A BIM-ENABLED PROCUREMENT FRAMEWORK IN NEW BUILDINGS FOR THE NIGERIAN ARCHITECTURE, ENGINEERING AND CONSTRUCTION INDUSTRY

By

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A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Civil Engineering and Surveying of the University of Portsmouth

DECLARATION

I declare that the work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. The work was carried out in accordance with the regulations of the University of Portsmouth and the material has not been submitted, in part or in whole, for any other degree at this or any other university

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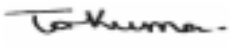
Signature: 

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ABSTRACT

The construction industry in Nigeria is one of the major contributors of the Gross Domestic Product (GDP) and as such a significant section of the economy. However, the industry adopted a fragmented approach due to the procurement variants and complexity in work. Procurement has a fundamental function in the execution of building projects in the Nigerian construction, architectural, engineering and construction (AEC) industry. The research aims at developing and validating a Building Information Modelling (BIM)-enabled procurement framework by investigating the willingness of the Nigerian AEC industry to adopt a BIM-based procurement process, particularly in new buildings.

Following the tenets of a pragmatic philosophy and an explanatory sequential mixed method approach, the study combined quantitative and qualitative approaches at intensive and extensive stages respectfully. At the early stage of the study, data was collected through existing literature review. Results of the literature review demonstrated that the following were issues in new buildings; abandonment, rework, poor performance, collapse, cost and time overrun, and fatalities. These issues were linked to procurement variants. Therefore, considering a collaborative technology/process such as BIM might remediate the problems. As such a questionnaire was developed based on literature review and analysed using statistical approach. As a means of validating the outcome of the conceptual framework developed, a focus group was conducted and analyse through coding.

The study suggests that there were several benefits of BIM that could be realised during the procurement and the adoption could improve integration of construction stages. Furthermore, for these benefits to be comprehended, several factors had to be considered. Such as innovation, free flow of communication, trust, encouraging initiatives, focusing a collective goals and objectives. However, the uptake of BIM in the nation had several barriers that were also investigated to comprehend the phenomenon further.

The study implies that the adoption of the BIM-enabled Framework could enrich both the management of new buildings and the adoption of BIM in the country. The contents of the framework should be viable for involved stakeholders when dealing

with procurement issues and BIM. By implementing this framework recommended in the study, substantial progress can be obtained in the issues encountered in the construction industry.

KEYWORDS: Procurement; BIM; Collaboration; Framework

DEDICATION

To my father, Engr. S. S. Jijingi for his unwavering support, encouragement, love, belief and guidance.

To my lovely mother Bar. M. L. Jijingi who prayed for me and advised me during difficult times.

To my siblings for their support and inspiration

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ABBREVIATIONS

Glossary of Terms

AEC Architecture, Engineering and Construction BIM Building Information Modelling

BOQ Bill of Quantity

BPR Business Process Re-Engineering

BS British Standards

BSI British Standard Institutes

C/S Consultant/ Supplier

CAD Computer-Aided Drawings

CAGR Compound Annual Growth

CDE Common Data Environment

CIC Computer Integrated Construction

DB Design-Build

DBB Design Bid Build

DL Direct Labour

EIR Employer Information Requirements FG Federal Government

FM Facility Management

FMPWH Federal Ministry of Power Works and Housing GDP Gross Domestic Product

ICT Information and Communications Technology IT Information Technology

LG Local Government

NBS Nigerian Bureau of Statistics

PC Project Consultant

PPP Public-Private Partnership

PTF Petroleum Trust Fund

RICS Royal Institute of Chartered Surveyors SD Standard Deviation

SG State Government

SME Small Medium Enterprise

SPSS Statistical Package for the Social Sciences UN United Nations

ARCON Architect Registration Council of Nigeria NSE Nigerian Society of Engineers

NIQS Nigerian Institute of Quantity Surveyors COREN Council for the Regulation of Engineering in Nigeria ZPMC Zonal Project Management Consultant

1

Introduction

1.1 Introduction

The introductory chapter was generated to present a summary of the thesis. Hence, this chapter contains the following: the details about the Nigerian Architecture and Engineering Construction (AEC) industry, the research problem, the formulated research questions, aim and objectives of the study. It also gives a fair knowledge of what the research is about, anticipated outcome and thesis structure.

1.2 Background of the Nigerian AEC Industry

According to Akinmurele, (2018) organised form of construction in Nigeria can be dated back to the 1930s. However, ten years after independence in 1960, the country witnessed a boom in oil production, which saw demands in the construction industry rise higher (Nigerian Bureau of Statistics, 2015). Nigeria is one of the most significant economies in Africa and has a nominal Gross Domestic Product (GDP) of over 285 billion pounds (Akinmurele, 2018). Nigeria is a developing country and is currently witnessing a massive boost in population growth as a result of increased migration, urbanisation and middle-class growth. The population growth has seen the requirements for improved living conditions such as better buildings, road networks and sewage systems that the AEC industry can provide (NBS, 2015). Mudi *et al.*, (2015) estimate the government will need about US$ 13 billion to US$15 billion annually to be able to meet up demands in new buildings. The federal government aims to address this with an increase in the recent budgetary allocation in housing (Okafor *et al.,* 2017).

Despite this, the Nigerian AEC industry is yet to achieve its potentiality as the country has a massive deficit in infrastructure. According to (Oluwakiyesi, 2011), the compound annual growth (CAGR) of the agricultural industry and oil industry is considerably higher than that of the construction industry as a result of its underperforming.

In Nigeria, this is a similar situation, and the industry is mostly involved in the construction of infrastructures, property development and also their maintenance (NBS, 2015). The AEC organisation is a very vital sector in any country's social, economic and environmental development. So many factors are responsible for this relevance. According to Adeagbo (2014), this is because the sector generates employment, sectoral links with other industries and as well as sustainable economic development with new buildings. According to the *Labour Force Statistics: Employment* (National Bureau of Statistics, 2017) the construction industry employs one million two hundred and forty-six thousand five hundred and forty-two people (1,246,542) and 98% are male, and 2% are female.

It is significant to note that the Nigerian AEC contributes enormously to the nation's economy. However, it has a complex structure in that it has a myriad of organisations. These consist of private and public companies/ clients, main/ specialist/ sub contractors, Small Medium Enterprise (SME), high and low technological organisations and builders, civil engineers with various disciplines of other construction specialists in the Nigerian AEC industry (Mudi *et al.*, 2015).

Procurement in the AEC industry defines the responsibilities of all involved stakeholders in new building construction projects (Love, Skitmore, and Earl, 1998). However, the currently adopted variants in the Nigerian construction industry fails to deliver new building projects and encounter several issues (Dada, 2013); A. Ibrahim, 2007). As such, conducting an examination on these variants utilised and comprehending the problems encountered as a result of the utilisation is essential.

1.3 Statement of the Research Problem

Dissimilar to other industries, the construction is more complicated and requires various stakeholders from different disciplines ready to acquire high demands of the

clients in buildings (Obiegu, 2005). The geographical emphasis of the study is Nigeria, which encounters several challenges that can be linked to the method of procurement methods (Luqman, Abiola-Falemu, and Ibironke, 2016; Dada, 2013; Ojo, Adeyemi, and Fagbenle, 2006). The spates of building issues in Nigeria is a growing concern in the construction industry (Hamma-adama and Kouider, 2017). New buildings in Nigeria over the past few years have had many issues performing as designed, being completed, collapsing and series of work reoccurrence causing delays and increase in cost (Ogwueleka, 2011; Olusegun and Michael, 2011; Oyewobi and Ogunsemi, 2010; Fagbenle and Oluwunmi, 2010). The issues that occur the most over the past few years have been those involving collapsing of the new building or uncompleted building and abandoning construction projects (Amade *et al.*, 2015; Muhammad and Adaramola, 2015).

According to Ayangade *et al.*, (2009) and Nigerian Bureau of Statistics (2015), most sophisticated and significant buildings in Nigeria are often have involvement from the federal government and closely followed by various state governments. The government embarks on several projects worth billions of dollars and the complexity of most of these projects requires expertise from disparate disciplines to be assembled into temporary teams to carry out the separate tasks to achieve a common goal. Emiedafe (2017) and Otunola and Olalusi (2012) pinpoint that Nigeria has issues on several construction projects for several reasons, one of which is the collaboration of multi-disciplines across the procurement phases. This need is echoed by Mudi *et al.*, (2015) who believes putting together a temporary team consisting of various industry experts such as quantity surveyors, architects, civil engineers and project managers makes an integrated approach challenging because of the conflict of obligations and goals. These issues are caused in most cases because of the adversarial culture developed through the method of procurement in the industry, which leads to fragmentation between the design and construction organisations.

Fragmentation of projects in the AEC industry occurs in two sections when utilising the Design-Bid-Build (DBB) construction procurement system; the "*construction work process*" (design) where there is notably a high level of division, and during the construction structure itself (Nawi Buluch and Bahauddin, 2014). These are the phases that the DBB separates and an area of interest for the study. The fragmented nature of the traditional procurement presents a need for an integrated approach that

can assist with collaboration. The establishment of collaboration is necessary because

it is vital as it brings together involved organisations and disciplines. The organisations involved in this carry out a crucial role in how they all collaborate to achieve set objectives on a construction project efficiently. In the AEC industry, most construction work relies on an integrated approach between the various project team members.

Various studies have established that an integrated project team can provide a competitive edge to organisations, increase productivity and other tangible and non tangible advantages (Burnard, 2007; Amabile *et al.*, 2001; Dyer and Singh, 1998; Tjosvold, 1986). It has been found that the efficient uptake of collaborative technologies is 80% dependant on resolving concerns in regards to the people and the process while the other 20% involves the technological issue (Shelbourn *et al.,* 2006; Wilkinson, 2005). The appropriate use of modern technologies could facilitate the integrated approach, thereby improving collaboration but only if a structured and systematic process is adopted (Pala and Bouchlaghem, 2012). However, this fact remains unrealised since most current research focuses more on technological issues instead of process and people.

At the moment, a notably critical discussed topic in the AEC industry and educational institutes are focused on Building Information Modelling. A technological multi dimensional and prominent collaborative process, BIM "*involves generating a visual model of the building which also manages data about it, at the design stage, throughout the construction phase and during its working life*" (Smith, 2013). Amongst others, the following were found highly beneficial when BIM was used on projects: increased coordination in the construction process, improved visualisation, the easy access of construction details and quantities essential for appraisal, installing and connecting of relevant information such as suppliers for distinctive materials. Also, noted were improved efficiency as a result of easy access to information, reduced project costs and collaborative environment for organisations. However, one of the most significant challenges it faces is that it lacks a comprehensive framework or implementation plan (Onungwa *et al.,* 2017; Abubakar *et al.,* 2014*;* Lu *et al.,* 2013; Azhar, 2011). Ertel, Weiss, and Visioni (2001); Gerschman and Schauder (2006) stated the relevance of collaborative practices particularly in a scenario with multiple stakeholders by highlighting that weak collaborative practices are the primary explanation as for the reason why construction project fails. However, adopting such

an integrated approach is not easy to maintain. BIM implementation in Nigeria is slow, and some studies demonstrate it is used in construction. However, it is only used as a

visualisation tool for clients (Abubakar, 2012).

Procurement methods are imperative to the success of the project as it defines the roles and responsibilities of involved stakeholders at inception, construction, utilisation and end life. As such, the system of procurement usually determines the outcome of the construction project (Dada, 2013). Most significantly, Love, Skitmore, and Earl (1998) believe that it provides a framework that structures and allocates responsibilities to all stakeholders involved in the project. Ibrahim (2007) suggests that for project objectives to be accomplished the procurement approach plays a crucial role. This is reaffirmed by Ofori (2006), who considers it significant to the performance and improvement in the construction industry. In Nigeria, the traditional procurement approach is referred to as the Design-Bid-Build (DBB). The process separates the consultant and primary contractor and only allows them to participate as separate entities (Idoro, 2012). This process is explicitly divided into three phases; the first which involves completing all design drawings for the bidding to take place in accordance with the design drawn. The second is the tender phase, where the client finds a suitable contractor for the third stage which is the construction phase.

Consequently, the traditional procurement approach in the Nigerian AEC industry has been criticised widely as an ineffective process to deliver the project as expected as it is adversarial in nature and separates the two major phases of the process which is design and construction (Dada, 2013; Babatunde *et al.*, 2010; Ojo *et al.*, 2006). The separation of these processes as a result of the procurement process creates a fragmented approach. The involvement of many stakeholders also creates a fragmented environment on construction projects.

Variants of the procurement system and BIM is a well-discussed subject in some construction industries. In the UK, a BIM roundtable discussion was conducted with industry experts knowledgeable in areas of collaborative procurement systems such as Public-Private Partnership (PPP) and Private Finance Initiative (PFI) (Smith, 2013). Several procurement variants suitable during the adoption of BIM were analysed; each procurement system came with several benefits and shortcomings that meant adopting BIM would be difficult. For instance, the construction management

system was a viable approach. However, the client had to be an expert in order for the adoption of the variant be successful. The design-build was also seen as a decent system but limited the client's involvement. In the United States of America, several

methods were examined, and Integrated Project Delivery and Design-Build were seen to be the best to incorporate BIM during construction (Bynum *et al.,* 2012; Wong et al., 2009). In Canada, Porwal and Hewage, (2013) understood that the inception of BIM would change the constructionework and developed another framework to aid with the adoption of BIM.

Wang et al., (2015) and Alufohai, (2012) both reviewed the adoption of BIM in Nigeria, the former examined it project cost management and the latter investigated it for the implementation among MEP firms in Nigeria. Furthermore, Hamma-adama and Kouider, (2017) and Onungwa et al., (2017) both examined the state of adoption BIM in the nation, with the latter going further to explore the use BIM as a construction management tool. Despite the recognised potential of BIM in delivering successful new building projects, very little research has been undertaken in its adoption in Nigeria for a new building (Koris and Kiviniemi, 2015). In Nigeria, while there are investigations regarding BIM adoption as listed, none explicitly examines the procurement variant suitable for its uptake and presents a framework to assist during the adoption.

Thus, the focus of this research will be on integrated processes in the Nigerian AEC industry and how this can improve the issues highlighted in buildings. BIM is centred on these discussions as they have proven to aid in the creation of a collaborative environment. The research will concentrate on specific features to create an explanation of the construction issues highlighted. These features identified will be used to develop a framework which can assist industry practices using BIM towards defined collaborative workflows.

1.4 Research Aim and Objectives

The fundamental aim of this research is to develop and validate a BIM-enabled procurement framework by investigating the willingness of the Nigerian AEC industry to adopt a BIM-enabled procurement process in new buildings. In order to accomplish this aim, the research developed and presented the following objectives:**20**

1. To examine and explore the currently used procurement processes and outline any constraints and issues regarding the currently used procurement methods.

2. To establish barriers to existing procurement methods for effective BIM implementation.

3. To conduct a proficiency and awareness level study of BIM in the Nigerian construction industry to establish the need for BIM adoption.
4. To explore the potentials, challenges and barriers affecting the adoption of BIM-enabled procurement in Nigeria.
5. To develop a BIM-enabled framework for effective BIM implementation in new buildings to aid in the uptake of BIM within the Nigerian AEC industry.
6. To validate the framework developed.

1.5 Methodology Overview

Since the research emphasises on developing a BIM framework with the traditional procurement approach in the Nigerian AEC, the study selected an iterative approach that with various advantages (section 4.2.1.4) to assist in collecting data for the research. Table 1.1 shows the proposed data collection technique and the objective that it addresses.

Table 1. 1: Proposed Methodology of BIM-enabled Procurement Framework in Nigeria

The aim of the Study: The fundamental aim of this research is to develop and validate a BIM-enabled procurement framework by investigating the willingness of the Nigerian AEC industry to adopt a BIM-based procurement process particularly in new buildings
Research Objectives Methodology Approach Research Actions

To examine and explore the currently used procurement processes and outline any constraints and issues

To establish barriers to existing procurement methods for effective BIM implementation

To conduct a proficiency and awareness level study of BIM in the Nigerian construction industry to and to establish the need for BIM adoption

To explore the potentials, challenges and barriers affecting the adoption of BIM in Nigeria.

To develop a framework necessary for effective BIM implementation in the Nigerian AEC industry

Robust literature review

Literature Review/ Questionnaire Survey Comprehensive questionnaire survey

Literature review/ Questionnaire

Literature review/ questionnaire/ focus group

Establish the context of the research

Outline how the current procurement process in Nigeria functions and problems that curtail the use of the process Establish the context of the research

Outline how the current procurement process in Nigeria functions and problems that curtail the use of the process. To generate a preliminary framework as a result of data from interview, questionnaire and literature review

To validate the framework developed Focus Group Validation of framework and create a final thesis

The collection of data starts with a robust review of literature in order to explore all

existing literature in the area of interest to the research. It explores issues regarding buildings ranging from performance, abandonment, collapse and fatalities and occurrence of rework in the AEC. It also examines how the project delivery method used influences the outcome of new buildings. Most importantly, it outlines areas for further interest during the second phase of data collection.

With the extant literature review, questions will be formulated in other to conduct a proficiency and awareness study. This questionnaire will assist in highlighting BIM deliverables in the country and highlight some parameter of what the framework will entail. The survey will contain four sections and will explore the following areas: background of participants; problems in the construction industry; BIM awareness and proficiency level and the Adoption of BIM in Nigeria (Potential benefits and the perceived implementation barriers/ challenges).

The BIM-enabled framework developed will be subjected to further review in a validation process. From the previous survey, participants will be chosen. These respondents will participate in a focus group to validate the framework. The results of the validation will be presented in a chapter. Another chapter will be developed for the contribution to knowledge, limitation, and further research focus.

1.6 Contribution to Knowledge

The contribution this research hopes to present is the BIM-enabled Framework (BeF) that promotes the use of an integrated approach which involves stakeholders in construction projects early and assists collaboration. The adoption of BIM in different nations presents different adoption barriers and challenges. Therefore, this research offers an understanding of these issues in a Nigerian context, mainly. Also, with the aid of the framework, a clear understanding of the responsibilities of the various project participants involved in various phases of construction projects when adopting BIM is proffered.

This framework will also improve the project performance of the construction process and potentially create a collaborative approach to construction projects in Nigeria.

Moreover, collaboration among stakeholders performs such a vital function in construction projects and can be noted as a further contribution to successful

productivity during construction projects. The study will also be an addition to the current knowledge that will stimulate future research about general issues concerning project delivery and the use of technological advancements in the nation to assist automation.

1.7 Thesis Contents and Structure

This section outlines the structure of the thesis and the contents it entails. Figure 1.2 demonstrates the flowchart diagram of the research. The research is divided into eight chapters, and they contain the following contents.

Chapter One: This chapter contains a background knowledge of the construction industry in Nigeria, the research problem to justify the research. After which, an aim is outlined with objectives. Research hypothesis with questions are also available in this chapter; a brief introduction of the methodologies that will be used to address the objectives is examined and; the anticipated contribution to the knowledge of the research is also highlighted.

Chapter Two: This contains secondary data about the current approach, the fragmented nature of this approach in the Nigerian AEC. It also, goes into details about issues of procurement, stating the connection between the procurement method in the construction industry and the effect on collaboration and integrated project delivery. The chapter concludes with clear reasons for the need to adopt new approaches.

Figure 1. 1 Flowchart Diagram of the Thesis Structure

Chapter Three: The section outlines a review of BIM in the Nigerian AEC industry, benefits, global adoption, implementation frameworks and the use in Nigeria. The chapter concludes with a comprehension of the uptake and further study required for the implementation in the Nigerian AEC.

Chapter Four: This chapter presents different philosophies of research, the research inference, method of data collection, research ethics and the strategy the sty has selected to address objectives in details. A summarised table is also presented that contains selections for the research with justification behind the selection.

Chapter Five: This will present the result and analysis of the BIM awareness and proficiency level study in the Nigerian AEC. It will also entail a detailed discussion

about the results and the relationship with the research. Furthermore, a conceptual framework will be presented based on the summative findings of literature reviewed and survey conducted.

Chapter Six: This chapter contains the qualitatively collected data analysis and discussion. Furthermore, the development and validation process of the final framework is presented in this chapter.

Chapter Seven: This will be the final chapter with comprehensive recommendations; limitations; future research and conclusion of the study.

2

Procurement, Variants, Process and Developments in Construction

2.1Introduction

This chapter aims at presenting an overview of some definitions of procurement, and what it means for the research. The chapter looks at the various types of procurement globally and examines further the system used in the Nigerian construction industry, what effects it has on project delivery. Finally, it highlights the relevance of collaboration among stakeholder and concludes with a summary of what the issue is and areas of discussion in the next chapter.

2.2Definition of Procurement in Construction

Procurement in the construction is an agreed means by which delivery of a project actualises set goals. According to Ibrahim (2007), there is relevance for the procurement method in a construction project because it is the key to accomplishing set out plans that are pertinent to the project. Love *et al.*, (1998) believes that when selected, it determines the general "*framework and structure*" which allocates duties and serves as a guideline for the construction process. In other words, the desired method impacts on time, quality, sustainability, cost and most significantly the success of the product delivery (Idoro, 2012). Kumaraswamy (1994) maintains that the mode of procurement has to be designed to suit the circumstance. Chan (2000) asserts that there is no such thing as "a correct procurement method" because according to Idoro (2012) whatever method aides in achieving the client's requirements and guarantees satisfaction and the end of the project lifecycle are deemed correct. As a result of this

difference in opinions, procurement in construction is defined differently by various

authors. Ibrahim (2007) observes the view that similar to some words in the AEC industry procurement has a myriad of definitions. Therefore, it is focal that area of study is well defined and understood. Table 2.1 shows some of these definitions to aid further understand the meaning of the concept. The relevance of understanding the procurement method on a project is vital to success.

Table 2. 1: Definition of Procurement

Source	Definition
United Nations Development Programme (UNDP), (2018)	*"Procurement refers to the process of acquiring goods, works and services. The process spans the whole cycle from identification of needs, choosing adequate procurement methods, sourcing suppliers and evaluation of their offers up to the award of the contract. An integral part of the procurement process is the management of the contracts and assets through the whole project lifecycle."*
Lohrey (2016)	*"In the construction industry, procurement refers to both the agreement of work description and the characteristics and functional relationship between and within this description of work."*
Masrom (2012)	*"Procurement is a strategy to satisfy the client's development and operational needs concerning the provision of constructed facilities for a discrete life cycle."*
Ashworth, Hogg, and Higgs (2013)	*delivery".*
Chartered Institute of Purchase and Supply Australia (CIPSA), (2005)	*"Procurement is the business management function that ensures identification, sourcing, access and management of the external resources that an organisation needs or may need to fulfil its strategic objectives."*
Enekwechi (2003)	*"Procurement is the contractual arrangement suitable for the delivery of a project in record time, cost and quality standard".*

Bower (2003)	*"Procurement is simply defined as the process of acquiring new products or services".*

Rowlinson (2000)	*"Procurement is an amalgam of activities undertaken by a client to obtain a new building".*
McDermott (1999)	*"Construction procurement can be defined as a framework within which construction is brought about, acquired or obtained".*
Love *et al.* (1998)	*"Procurement is an organisational system that assigns specific responsibilities and authorities to people and organisations, and defines the relationships of the various elements in the construction of a project."*

Table 2. 2: Definition of Procurement

Rowlinson (1999) an ill-defined procurement system, can see a simple word like "*construction*" confused and responsibilities confounded. It can be established from Table 2.1, that there is no generally accepted definition of procurement in the construction industry. However, procurement in the construction industry consists of several processes over various phases that are interrelated and involves several stakeholders' contributions sequentially. For this research, "Procurement" is used in a context of construction and refers to the "*the process by which one obtains construction projects, manages it from inception to handover with all the involved stakeholders and deliver a satisfactory construction project to the client*." The definition is deduced from some of the already available ones in Table 2.1; this is to ensure that the study tackles any aspect of construction procurement that could influence the adoption of any recommendation proffered by the study.

2.3Types of Construction Project Procurement System

There exist variants of methods by which procurement can occur in the construction industry. There are four classifications of procurement systems and are as follows: traditional (separated); integrated; management orientated, and collaborative (Davis, Love, and Baccarini, 2008). The four systems have been increasing over the past decade and had sub-classifications in response to market demands. These systems also have various variants that have been designed to suit the purpose on different

occasions. While this classification exists, it is essential to note that Ramus and Birchall (1996) believe that some of the variants are often a combination of different systems. Therefore, there are similarities in with most variations from different systems. Figure 2.1 presents an organogram of the various system. Procurement is crucial to the

performance of the project and has brought about changes not only in the project delivery but also in the management and organisation.

Figure 2. 1 An organogram of the procurement systems

Under the separated/ cooperative system, the conventional method is the traditional method. The traditional method of project procurement is "*design, bid and build* ". Rashid *et al.* (2006) believe that this system is sub-divided into two categories, namely: sequential and accelerated method. The sequential method allows the client to appoint a designer (consultant) who produces the drawings of the proposed facility. These generated drawings are subject to a tendering process, and a contractor is selected.

Given that the drawings and specification produced by the client's consultant, the contractor constructs the facility. In the case of the accelerated method, as the name

implies is a similar process but is sped up in the area of contractor selection. According to Rashid *et al.*, (2006), this method sees a few numbers of specialist contractors selected, preliminary discussions with them and submission of fixed tenders.

With the integrated system, it combines phases that will typically be separate entities into one. As the name implies, it integrates and incorporates the design and construction responsibilities and narrowing to one contracting organisation (Ashworth and Perera, 2018). The integrated system has three major types of variants; develop

and construct, turnkey contract and package deal. Develop and Construct is an integrated procurement that requires the client to have a schematic of the design and with that appoint a contractor who takes over and produce the final design and constructs the finished product (Babatunde *et al.,* 2010). The word "*Turnkey"* is an American term that means upon completion; the keys are handed over to the client, who then has access to the apartment by "*turning the key*" (Rashid *et al.,* 2006). This process means the contractor will be required to design, construct and provide equipment for fully operational infrastructure. Constructing Excellence (2004) defines package deal as an approach that requires the primary contractor to produces a straightforward project subject adjustment in size. These can be factories, straightforward official complexes and warehouses.

The management-oriented system places more importance on the management aspect of the design and construction of the project than other methods. There are several variants of this system in construction procurement. Management contracting, according to Davis *et al.,* (2008), is a system that involves a client appointing a construction management contractor. This system allows the contractors to perform in an advisory capacity during the pre-construction phase and handle all construction activities. It also allows the client the flexibility to change designs and kick off the project earlier than agreed. Construction management is a method that usually identifies a construction management contractor through a thorough selection process and pays the contractor a fee upfront. According to Babatunde *et al.*, (2010), this method allows the client to wield more power as the construction manager communicates directly to the client, and this process makes the manager the only a consultant to the client. In the case of design and manage, the responsibility of managing the design and construction of the whole work is that of the appointed contractor.

Primarily, the collaborative system has a higher usage in complex projects. The system sees an alliance or partnership formed with two or more organisations who have identified the benefits of sharing resources to achieve a common goal. Burnard (2007) defines it better as: "*An effective way for more than one client, contractor, consultant or supplier to join together to procure works, services, materials or goods, share expertise, promote efficiency and deliver value for money savings in the delivery of a project or service objectives".*

2.4 Construction Procurement of New Building Projects in Nigeria

Construction is a significant contributor to a nation's GDP, and that is not different in the case of Nigeria. Oluwakiyesi (2011) believes while the percentage of contribution may not be currently as high as in previous years, it remains vital to the stability of the economy. However, the industry continues to underperform and is bedevilled with a combination of low productivity and poor performance over the decade (Abubakar *et al.*, 2014; Ogunsanmai, 2013; Adeyemi *et al.,* 2005). According to Ibrahim (2007), the industry comprises of "*formal, organised sector and unorganised informal sector*". The formally organised part consists of foreign and domestic construction organisations. The classification of these organisations can be small, medium and large based on the amount of capital and size of the workforce. Adeyemi *et al.* (2006) estimate that the construction industry has about two million workers. These workers are ranging from carpenters, decorators and masons, joiners, roofers, civil, mechanical and electrical engineers; tillers, painters, plumbers, bricklayers, joiners, plants and machines operatives, plasterers, glaziers, heating and ventilating engineers and other disciplines. The figure can potentially be higher as the population and workload have exponentially increased since 2006.

The public sector is the primary financier in the Nigerian AEC industry that stimulates growth and development in the Nigerian economy (Isa *et al.,* 2013). The reason for public government high performance in the nation's construction sector is as a result of low investment from the private sector. However, with the recent expansion of the industry and government using financial incentives, the private sector has demonstrated enthusiasm in investing in the AEC industry. The interest is also to bridge Nigeria's growing infrastructure gap.

There are two significant categories of Procurement for new building projects in Nigeria, which is the traditional and non-conventional methods (Ojo *et al.,* 2006). As recorded in the past, Ibrahim (2007) highlights that most construction projects in the nation are sponsored through the budget allocation of the three-tier (federal, state and local government), as highlighted in section 1.1. Most clients in the country predominantly use the traditional procurement, but also they do use some of the non conventional projects depending on the type of work (Babatunde *et al.,* 2010).

2.4.1 Traditional Procurement

Design-Bid-Build is also knowns as the traditional method of procurement in Nigeria.

This method entails three sequential stages; the design phase, the tender phase and finally the construction phase. Davis, *et al.*, (2008) highlight that the traditional method was initially designed for use in the military and entailed; an inclusive design of the project, advertisement of the construction project and awarding the contract to the tender that matches the desired criterion. According to Babatunde *et al.*, (2010) these phases are usually separate entities which means contractors bid for the contract after a consultant has designed the building in accordance to the client's requirement alongside a quantity surveyor. This process allows contractors to tender competitively in an environment similar to a competitive market.

Figure 2. 2 Illustration of the Design-Bid-Build (DBB) Method

Figure 2.2 demonstrates the traditional process operates. The dotted arrows imply the delivery of services procured by the owner. There is a belief that the method derives some of its attribute from Adam Smith's division of labour concept where specialisation is promoted (Dada, 2013). This concept believed that separating task into various entities and allocating the responsibility to a specialist will improve productivity and improve performance. Turner (1997) stated that the use of the traditional method should be primarily put in to use in the following scenarios:

- When the project quality required is high
- A construction schedule that is not needed urgently and has sufficient time
- Require a particular design by a consultant
- When a client wishes to divide design and construction separately and when the client is happy to share the risk with the principal contractor

This method, like other procurement, comes with various advantages and disadvantages; Table 2.2 outlines a couple of these.

Table 2. 3 Benefits and Shortcomings Design-Bid-Build in the Nigerian Industry (Traditional Methods) (Source: Okore *et al.*, 2017; Davis *et al.*, 2008; Ojo *et al.*, 2006)

Advantages	Disadvantages

DBB allows accountability because of the competitive nature of the selection process.	DBB is sequential, and it is famous for being a time-consuming process and not known for urgent projects.
All contractors that tender is done so on an even basis because all the available documents are made public and advertised.	The contractor does not have an input in the design or planning phases, and as a result, might encounter difficulties during construction.
The construction market is very familiar with the use of DBB. Therefore, all stakeholders' responsibilities are well defined.	This process can lead to dispute and blame allocated around when issues arise.
The process is transparent. Therefore, all decisions made are open to scrutiny if anyone disagrees with it.	Project under this system of procurement is known to overrun most of the time, with a lot of unseen delays and cost. The owner (client) is financially responsible for any errors that may arise as a result of design during construction.
The process allows negotiations and award of contract based on the best value. The process eliminates bid that may mistakenly below.	

Governing the use of traditional procurement in Nigeria are rules produced by the government. These rules are set and designed by the "*Public Procurement Act 2007 (PPA) and the Infrastructure Concession Regulatory Commission Act 2005 (ICRC)"* (Okafor *et al.*, 2017). These laws state that there has to be a formal bid or tender process; therefore, as illustrated in Figure 2.1, the owner (a government agency) receives the drawing back from the consultant. The design of the projects is a result of a detailed functional brief of the project objective; this brief reflects the client's requirements. This brief is crucial as identifies all the projects objectives, constraints and feasibility. According to Cheong (2004), taking all of these into consideration, the designer solves it by submitting viable drawings. Electrical, structural and mechanical engineers thoroughly examine the drawings; this is to ensure details are present for a bill of quantity to be derived by the quantity surveyor (Ojo *et al.,* 2006). The Bill of

Quantity (BoQ) provided by quantity surveyor serves as a yardstick which the client uses in the tender phase when potential contractors bid.

With the availability of the design and a BoQ to the client; the design is advertised for potential main contractors to bid. The primary contractor employs various trade specialist in areas where they cannot complete the work based on their expertise unless agreed explicitly to complete work on their own with the client. The PPA states that all procurement of services, works and goods must be done using competitive bidding. It, therefore, allows the public entity to:

- Advertise work and demand a proposal or intent of interest (Sequential) • In a situation where it is an emergency, the public entity can engage in direct procurement (Accelerated)

In a case that the primary contractor is not obliged to execute the whole project on their own. They can, therefore, employ specialist trades to do so in areas they cannot. The trade specialist (sub-contractors) are not involved in the procurement phase but have a decisive role in the delivery of the project. With the DBB process, the simple laws of contracts are used as they are employed to perform a particular job and receive payment upon completion unless agreed otherwise. According to Hinze and Tracey (1994), trade specialist carries 80-90% works on most complex projects. (Olatunji, Olawumi, and Odeyinka, 2016) postulates that the main contractor primarily provides guidance and coordination amongst these trade specialists.

2.4.1.1 Fragmented Nature of Traditional Procurement

It is essential that the involved clients, trade specialist, designers and contractors work collaboratively in achieving the desired objectives of the clients. However, that is not the case with this process. The industry is fragmented, and this is averred by (Idoro, 2012) that it is the contributing factor to AEC industry's poor performance. Engeström, Engeström, and Kärkkäinen (1995) suggest that fragmentation may make it impossible for organisations from a different context to "speak the same language" and even exchange solutions or ideas on a problem.

Fragmentation of projects has been noted to occur in two divisions within the traditional procurement; the design process where the integration of contractors is very significant and the construction work itself where the input of the designer is relevant

in most case (Nawi *et al.*, 2014). Therefore, as demonstrated in Figure 2.1, the first incident of fragmentation will occur when the owner (Governmental Agency/ Ministry) separates the design and construction process. This process is so adverse that it has seen the contractors in the construction industry request for an early contractor

involvement, thereby integrating design and construction (Ojo *et al.,* 2006).

It also does not reflect the current requirements of an integrated process when designs are intricate in the modern AEC industry. Therefore, the fragmented character of the first phase presents a severe difficulty on the ability of the traditional method of handling building projects.

The second part of the fragmentation occurs upon selection of the trade specialist to construct. Their issue with the selection process is that; this focuses typically on the trade specialist capability solely rather than their collective ability to collaborate and work together efficiently (Baiden, Price and Dainty, 2006). Selection done this way leads to excessive design changes making the right project life-cycle analysis challenging to achieve. Nawi *et al.* (2014) believe that these issues are crucial and significantly influences the efficiency and effectiveness of the project performance. In the Nigerian industry, this responsibility is that of the main contractor, but several researchers have encouraged that the selection process should be based on collaborative attributes and capabilities (Dada, 2013). The traditional project delivery method in the Nigerian AEC industry has meant extensive criticism as an ineffective method, but yet it remains unchanged. This conclusion we derived from extensive research where the DBB procurement tends to overrun regarding cost and time in most construction projects in the nation (Dada, 2013; Idoro, 2012; Ojo *et al.,* 2006). Other countries in the various region have turned their attention to a method that is much more collaborative and involve the use of collaborative technologies within the traditional procurement methods (Abubakar *et al.,* 2014). However, it is vital to note that a research for residential buildings in the country, Ojo *et al.,* (2006) found that for projects below 5 million Naira (£10,000) the success rate of the use of the traditional procurement was satisfactory.

2.4.2 Non-Conventional Method

In the Nigerian AEC industry, several non-conventional methods are put to use in public procurement. They are the Design and Build (Mohandesa, Hamidb and

Sadeghic, 2014), Management Contracting, Direct Labour (DL) and the Public-Private Partnership (Babatunde *et al.,* 2010; Ibrahim, 2007; Ojo *et al.,* 2006; Hassan, 2004).

2.4.2.1 Design-Build in Nigeria

The DB method can be dated back time of the creation of historical infrastructures like the pyramids, where a master builder was appointed to manage the whole construction project (Okore *et al*., 2017). However, in the case of Design-Build as described in section 2.2 is a method that allows the client to select an organisation to be responsible for both design and construction of the whole project instead of separate individuals for the two stages. The process uses the request for proposal (RFP) procedures rather than invite companies to bid like the DBB. This process fosters collaboration between the design and construction teams as they can begin developing drawings jointly and promotes a reassessment of drawings as it advances for buildability in the construction phase (Akpan *et al.*, 2014). The issue of the DB method in the Nigerian industry was a problem regarding client satisfaction. Idiake *et al. (*2015) believed that this issue arose as a result of an inadequate functional brief in the inception stage of the project. The inadequacy reflects on the outcome of the project because the contractor involved in the project was ill-advised of the project objectives. Ojo, Aina, and Adeyemi (2011) went further in a comparative analysis with the traditional method in the nation, pointing out that for improved client satisfaction with DB method, the client should make sure their selected representative is fully involved in the design process. The involvement of the representative chosen is to make sure the client's objectives are not neglected as the project is embarked upon until the project is realised.

2.4.2.2 Management Contracting in Nigeria

According to Hassan (2004), the use of management contract procurement was in the '90s for Petroleum Trust Fund (PTF) rehabilitation programmes that occurred in a massive capacity in the country. The purpose of this method was, therefore, primarily to rehabilitate essential infrastructure across the nation. The PTF was created as a result of long bureaucracy, cost and delays in a construction project by governmental ministries/ agencies. PTF was therefore to use a different form of procurement that eliminates these problems.

Figure 2.3 Organogram of the organisational structure of the PTF Programme (Yusuf and Adeyinka, 2003)

Figure 2.3 demonstrates how PTF used management contracts in Nigeria to move from traditional procurement. The PTF Board of Trustees selected a company called Afri Project consortium as the management contractors for all the rehabilitation projects (Yusif and Odeyinka, 2003). Six Zonal Project Management Consultants (ZPMC) were appointed for the six geopolitical zones in the nation and under them were Project Consultants (PC) whom the Contractors/ Suppliers (C/S) reports depending on the discipline. This process met criticism, and since the defunct of the PTF, the public government rarely uses this method (Ibrahim, 2007). After the disestablishment of PTF in 2000, Yusif and Odeyinka (2003) researched some PTF projects in the North West geopolitical zone and noted that projects have no cost overrun and quality of work was neither satisfactory nor dissatisfactory. However, the project programmes in that region experienced 38.5 % time overrun; 72.6 % of were behind schedule, and 17.6% were at zero completion.

2.4.2.3 Direct Labour in Nigeria

The direct labour procurement technique is also known as "*in-house*" procurement in the Nigerian industry. This method primarily involves three variations. The first variant includes the staff of the client designing and supervising the construction of a

contractor; the second is vice versa and consists of a contractor/ consultant designing while the staffs of the client carry out construction. The final variant is called "*in*

house design and construction." which allows the teams of the client to execute both design and construction (Idoro, 2012). The use of the Direct Labour (DL) exist in the Nigerian AEC industry but in a minor capacity. Many stakeholders at all tiers of government widely understand this method, as Oladapo (2003) noted and some governmental agencies use it for "*minor maintenance or new works of minor nature* (Ibrahim, 2007).

2.4.2.4 Public Private Partnership (PPP) in Nigeria

There are also several variants of a system referred to as, the Public-Private Partnership. The United Nations Economic Commission for Europe, (2018) defines public-private partnership as *"a long-term contract between a private party and a government entity, for providing a public asset or service, in which the private party bears significant risk and management responsibility, and remuneration links to performance*". PPP method of procurement allows the government and private entities to provide infrastructural requirements for the nation. The emergence of various types of PPP exists within the literature. The variant of PPP chosen depends on the circumstance according to Rodriguez, (2017) this choice is narrowed down to the available selection and magnitude of the project. Mentioned, defined and tabulated in table 2.4 are a couple of these options.

Table 2. 4: Types of PPP and definitions (Rodriguez, 2017; Babatunde *et al.*, 2010; Thai, 2008) **Variants**

Definition

Design, Build, Finance and Transfer (DBFT)

With DBFT, the private entity funds the whole project privately. An agreement after construction will allow the private entity to own the project for a while till transfer.

Joint Venture (JV) JV under PPP contracting requires equity at stake, and in this case, all profits and risk are divided based on the percentage of stake every individual owns. Risk management is allocated to parties according to their areas of experties to enhance overall risk control.

Design, Build, Finance, and Operate (DBFO)

Build, Rent, Transfer (BRF)

Build, Own and Operate (BOO)

Build, Transfer and Operate (BTO)

Build, Own Operate and Transfer (BOOT)

The private group provide everything for the projects and operates the infrastructure. The public group delivers funding when the infrastructure is in use. The public group can also handle land acquisition and resettlement since it is backed by law or if necessary is able to make laws to enhance its powers in this respect.

The BRF process permits the private entity to design and build the facility and transfer it back to the public or governmental partner.

This process is similar to privatisation. BOO allows the private organisation full ownership and is liable for all profits and losses of the facility.

Under this type, the private entity design and builds the facility/ infrastructure and the governmental entity. The public partner leases the facility/ infrastructure on a long-term to a private entity to manage.

The private organisation is given full ownership of the infrastructure upon completion of construction. However, this is later relinquished to the governmental body in a fully functional state in the initially agreed period.

Build, Operate, and Transfer (BOT)

Build, Own, Operate, Subsidize and Transfer (BOOST)

Renovate, Operate and Transfer (ROT)

Build, Lease and Transfer (BLT)

IM/ IS (Investment Management and Investment Services)

This variant is similar to the BOOT as is the private organisation to use the fully functional project and transfer back the public partner. However, the state of the project upon transfer can be unfunctional.

In this case, a financial incentive is offered to the private consortium in form of a subsidy during transfer to provide a profit.

In this scenario, the private company refurbishes an existing infrastructure and is allowed ownership until recuperation investments. Upon recuperation, the infrastructure transfer occurs back to the original owner, which is the public entity. This variation allows the private entity to lease the built facility/ infrastructure to the consortium over a given period. After profits have been realised in that period; the governmental body involved collects the facility back. Herein this variant permits simultaneous management by an investment or management association of the completed infrastructure for both the private developer and the governmental body to recuperate capital. After which a transfer occurs back to the public partner (government).

Table 2. 5: Types of PPP and definitions (Rodriguez, 2017; Babatunde *et al.*, 2010; Thai, 2008)

PPP model was officially adopted in 2005 by the Nigerian government for efficiency in project delivery (Dominic *et al.,* 2015). The use of PPP was to create a collaborative solution to issues of procurement plaguing the construction industry. It was also used as an incentive to encourage private sectors to invest in construction projects as the government noticed catering for infrastructure deficit on their own was not feasible. In Nigeria, the most common variant of the PPP used is the Build Operate Transfer (BOT) and Joint Venture (JV) for both new, refurbished and rehabilitated projects (such as bridges and road construction, estate and housing development, car parks) (Ibrahim, 2007). Also, for facility management (conference centres) (Ikpefan, 2013; Ibrahim, 2007; Ojo *et al.,* 2006). This research also corroborated these findings that the BOT remains the most popular form of PPP in the Nigerian AEC.

In Nigeria, PPP is one of the most commonly used procurement methods in Public procurement. Among the three tiers of governments, only Lagos State out of the 36 states has been able to use PPP in construction projects effectively (Sanni, 2016). The emergence of a new government in 2015 witnessed a renewed interest in PPP, with the federal government embarking on several PPP projects (Ugwuanyi, 2016). The success of these projects is yet to be confirmed as some are still in the early stages of planning, and a few awarded ones have delivery dates in the future (InfraPPP, 2018).

Table 2. 6: Similar Studies on Procurement in the Construction Industry

Source	Title	Problem	Solution
Ateloye, Bowles, and Oyegoke (2016)	*"Private Sector Participation in Nigeria Higher Education Infrastructure Development"*	The study aimed at establishing how the utilisation of PPP could assist collaborative approaches to proffer solutions to challenges encountered in higher education systems.	The outcome of this study was a recommendation of a system/ procedure that can provide an environment of trust and a reduction of corrupt practices.
Dada (2013)	*"Client and Consultant Organisations' Assessment of Design-Bid-Build Procurement Practice in Nigeria"*		

Idoro (2012) *"Comparing the Planning and Performance of Direct Labour and Design-Bid-Build Construction Projects in Nigeria"*

As a result of the criticism of the use of the traditional procurement process in Nigeria, this investigation asked the client and organisations in the industry to comprehend the adoption of the technique. With the continued use of the traditional procurement, and numerous criticisms on the process. This research aimed to comprehend why the process was still widely used both in the private and public sector.

The outcome of the investigation was a recommendation a further examination to explore further into the process.

Findings revealed that homogeneity of perceptions about the traditional procurement be a springboard and form a baseline for further intervention efforts for the improvement of projects.

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Dada (2011) *"A Second Look: Stakeholders' Perceptions of Some Issues in Design-Bid-Build Procurement Practice in Nigeria"*

Abiodun (2012) *"The Role of Public-Private Partnerships in Highway Infrastructure Development and Sustainability in Nigeria"*

Awodele (2012) *"Framework for Managing Risk in Privately Financed Market Projects in Nigeria"*

The study examined the perception of the DBB process by stakeholders in the Nigerian AEC as result of the drawbacks and issues that had arisen when the traditional process was adopting and the emergences of new alternatives as a replacement.

Nigeria, as a country has an infrastructure deficit and sustainability crises, the conventional procurement methods are failing to deliver on the quality and quantity. The study seeks to examine PPP as a collaborative solution to these issues. With the use of the traditional procurement in the Nigerian AEC industry not delivering, this study sort to provide a risk-sharing process using PPP to improve project performance.

The perception of the stakeholders was a homogenous such that they suggested improvement was required to improve AEC projects in the country.

A framework was developed using the DBB and PPP procurement, providing a holistic approach to achieve sustainable highway infrastructural projects in Nigeria.

A framework was developed to assist stakeholders during a construction project in Nigeria learn during the application of PPP and aid comprehension of viable options for effective management.

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Ojo, Aina, and Adeyemi (2011)
"A comparative analysis of the performance of traditional contracting and design-build procurements on client objectives in Nigeria."
The performance of both design-build and the traditional procurement were investigated to understand, which stands a better chance of delivering the satisfactory objective of the clients.
The study demonstrated the design and build was more effective than the traditional procurement in terms of client's satisfaction for quality, cost and time.

Ibrahim (2007) *"The development of a Procurement Strategy for Primary Health Care Facilities in Nigeria."*
As a result of the current system's failure at providing sustainable and integrated Primary Health Care (PHC) facilities in Nigeria, the study targeted developing a new procurement

strategy.

A comprehensive framework was developed using PPP to ensure that planning, design and construction into occupancy and post-occupancy become an integrated approach during procurement of PHC facilities.

Ojo, Adeyemi, and Fagbenle (2006)

"The Performance of Traditional contract procurement on Housing projects in Nigeria."

With the criticism of the traditional procurement causing cost overrun and delays, the study sort establishes if this was the case and if it can proffer a solution.

Cost analysis on over 57 housing projects was conducted. The study concluded that while the traditional procurement remained ineffective. It could still be used for specific housing projects if slippage is reduced.

Table 2. 7: Similar Studies on Procurement in the Construction Industry

Table 2.4 indicates the current use of several procurement methods in the Nigerian AEC industry. It also summarises available literature on the criticism of the traditional procurement method and the solutions proposed by the studies. These studies were conducted to evaluate the use of several procurement methods in Nigeria and recommended a newly improved collaborative procurement. Ojo et al., (2011) and Ojo et al., (2006) both reviewed the traditional method and discovered it was a process that lacked collaboration as the contractor involvement was only during the construction. Several studies attempted to find a different route and comprehend any issues that may arise as a result of selecting the procurement route. Dada, (2013); Dada, (2011) and; Idoro, (2012) investigated the design-build procurement; the investigation revealed that design bid build could not efficiently replace design bid build as this procurement route does not allow risk to be evenly distributed. Abiodun, (2012); Awodele, (2012) and; Ibrahim, (2007) evaluated public-private partnership in other to distribute risk and improve collaboration instead of the design bid build, adopting this came with issues of ownership and lacked guidelines as the process was relatively new and remains unsuccessful mainly in Nigeria. Ateloye et al. (2016) examined PPP in higher education and established a need for collaborative practices.

In conclusion, several variants of construction procurement in Nigeria do not encourage collaboration amongst stakeholders, but rather create a fragmented delivery approach. However, the study intends to examine these construction methods (DBB,

D&B, DL, Management contract and PPP) to evaluate what is most used and establish an integrated delivery approach.

2.5The Requirement of a Collaborative Approach in Nigerian AEC's Procurement Process

Abuelmaatti and Ahmed (2014) point out that there is a high collaborative requirement with the system of procurement in construction due to its multi-stakeholders and adversarial nature. Kale and Arditi (2001) also state that one primary contractor cannot finish a project on their own. Therefore, the specialised nature and the relation between them and other involved organisations is crucial to the desired outcome. The definition of collaboration in this context is "*a creative process undertaken by two or more*

interested individuals, sharing their collective skills, expertise, understanding, and knowledge (information) in an atmosphere of openness, honesty, trust and mutual respect, to jointly deliver the best solution that meets their" (Wilkinson, 2005). Xue, Wang, Shen and Yu (2007) believes the DBB method to engender adversarial attitudes when collaboration is necessary. It imperative that the reasons for collaborations be understood, and different stakeholders in a construction project are integrated efficiently and assiduously. Also, it is relevant to comprehend the consequences of detrimental issues that may arise if construction is not carried out in a collaborative system.

2.5.1 The Integration of Design and Construction in Procurement

In the context of this study, integration can be referred to as the interdisciplinary sharing of data, method and different goals between design and construction stakeholders (Tatum, 1987). Furthermore, Bosher, Dainty, Carrillo, and Glass, (2007) established that integration with the involvement of various project team members is not "*project's random integration solution*"; instead it is specific to multiple stages of the design-construction-operation process. Therefore, to ascertain the high level of integration required in a new building project, a collaborative effort among the project team is required (Baiden *et al.,* 2006).

It is relevant to understand when to integrate the parties involved at the right time within the right sequence (Kim, 2014). Gould and Joyce (2011) aver that design is

deemed to be suitable when it is the result of multidiscipline collaboration. There is a widespread acceptance of integrating design and construction in a building project as opposed to the traditional method that separates these two processes (Idiake *et al.*, 2015; Sødal *et al.*, 2014; Idoro, 2012).

Figure 2. 4 American Institute of Architectures (AIA) adoption of an Integrated Design compared to the traditional process in America (AIA, 2007)

Modern construction projects demand a high level of technical support and intricate design to meet bespoke client requirements (Eriksson and Westerberg, 2011). In realisation of this fact, the AIA developed a procurement approach that entailed integrating all significant stakeholders in a construction project as early as the decision-making phase. Figure 2.4 demonstrates the inclusion of team members in the

conceptualisation phase this, in return, improves collaboration and improves project performance. When using the traditional method of construction, (Doloi *et al.*, 2012) observed that there is sometimes inadequate understanding of the client's demands, and this inadequateness is reflected in the drawings. In most situations, the client usually is not an expert in design and can only take the word of the architect on the appropriateness of the plan the architect has produced, however, with the use of traditional procurement in public service. The ministry or governmental agency in Nigeria has qualified civil engineers, architect and quantity surveyors that act on behalf of the government as the client and review these design to see if they are fit for purpose (Okafor et al., 2017).

Nevertheless, according to Santos and Ferreira (2008), even experts and professionals are subject to occasional costly errors when reviewing dense or unconventional building drawings in 2D. Analysing this design involves mentally envisaging and examining these drawings. This process demands years of experience in design and construction and spatial abilities. Also, this system does not give a lot of space for automated designs. As a result of which editing or correcting designs become difficult.

The abundant issues have been recognised that can lead to another problem called buildability. Buildability is the appropriate application of the construction and design understanding in the inception phase of construction, especially procurement to accomplish the purpose of the project (Wong *et al.*, 2007 and Trigunarsyah, 2006).
The concept was in realisation of the fact that both designers and contractors perceive the same project from different viewpoints and it is pertinent that for the optimisation of the project result all inputs are required from the inception stage (Akpan *et al.*, 2014). Buildability primarily affects the quality of the buildings when finally completed. This issue arises as a result of seclusion between construction professional and the technical developer (architects). Buildability emphasises the integration of design and construction to develop a clear understanding of designers intentions during construction and contractors abilities during design. (Wang, *et al.*, 2013), reaffirms this point and also believes issues like maintenance and facility management be envisaged during the inception phase too. Therefore, the whole lifecycle perspective of the building/ facility/ infrastructure is considered in the design phase to enhance the overall performance. The concept of buildability/ constructability is not new in Nigeria. However, a research conducted by Akpan *et al.*, (2014) highlighted the "*it is one thing to be aware of a utility and another to utilise it*". Akpan *et al.* (2014) suggested that

buildability is added to a contractual clause in the nation to encourage industry practitioners to use it.

In extensive research by Ibrahim, *et al.,* (2013) thirteen (13) key practice indicators for integration were highlighted and explained after been categorised into two groups, which are Non-relationship and relationship-oriented. Tabulated in Table 2.5 are the different indicators of project team integration practice.

Table 2. 8 Indicators of Team Integration (Adopted from Ibrahim *et al.*, 2013)

Indicators of Team Integration	
Non-relationship Oriented	**Relationship Oriented**
Creation of Single Team Location	Trust and Mutual Respect
Effective Management, Safety and Health	objectives
Focusing on collective goals and	"No" Blame Culture
Integrated ICT System	Collective understanding
Innovation & Improvement	Free Flow of Communication
Client care team	Commitment from stakeholder
Encouraging initiatives	
Seamless operation with no organisational boundaries	

These indicators/ conditions are necessary for the design and construction project teams to effectively and efficiently be integrated to create a collaborative environment. It is essential that for a needed change to occur the indicators in Table 2.6 are utilised in the integration process.

Finally, for a project to be ascertained to have a collaborative environment as an outcome of the integration of design and construction, the following identifying characteristics separate a collaboratively delivered project and traditional procured project (Ghassemi and Becerik-Gerber, 2011):

- the early and constant inclusion of crucial organisations
- clear task and obligations, and clear lines of information exchange

- a collaborative project team consisting of architects, client, contractor, specialist trades and facility management teams
- a collaborative design process that considered buildability during construction and operation during facility management

This section examines the relationship between collaborative practices and the integration of stakeholders on the construction project. And as such outlines the

thirteen indicators of integrative behaviours. Further evaluation of these indicators in the Nigerian AEC is relevant to establish if the same opinions are echoed by those in the industry.

2.5.2 The Outcome of the Fragmented Design and Construction Approach in Nigeria

It is essential that a project's characteristics not be misunderstood as Smith, (2002) suggests it can likely lead to reduced delivery processed and higher cost. Moreover, the misunderstanding of a project's characteristics can directly result in a process that is not only defective but unproductive. For that reason, the planning of design implementation becomes even more critical as the complexity of design increases. Unlike traditional buildings, buildings aiming to be productive have a lot more delivery constraints because it is viable (Kibert, 2007; Horman *et al.*, 2006).

Issues arising as a result of the division of design and construction teams can arise exponentially and cause various complication in new buildings and construction projects. Highlighted are some of the current difficulties encountered in the construction industry in Nigeria:

2.5.2.1 Occurrence of Rework

The Nigerian construction industry has seen a ridiculous amount of projects overrun in cost riddled with delays as a result of reworks. In a thorough investigation into reworks in Nigeria, Oyewobi and Ogunsemi, (2010) pinpointed that the primary causation was conflicting information between the construction and design team. Other factors causing rework was inexperienced workers and inadequate construction planning. Rework in the construction industry has a severe ripple effect on the outcome of the construction project. Oke and Ugoje (2013) believe that substructure had some of the complicated design, and this was reflected as there was the highest amount of

reworks in most projects examined in their investigation. Oyewobi *et al.*, (2011) in a case study of rework in Nigeria concluded that to contain or eliminate rework; there was a need for a general agreement to bring together the client, contractor and consultant in a collaborative environment from the inception of the project. Oyewobi *et al.*, (2016) also pointed out in a paper that it is essential that stakeholders understand that while collaboration presents a significant solution to

issue regarding rework, it necessary to understand that different factors can also lead to rework. Therefore, it is crucial that management pay adequate attention to several factors that can lead it to adversarial issues resulting from reworking and mitigating through teamwork.

2.5.2.2 Collapses and Fatalities

The collapse of buildings around Nigeria, present governmental bodies with huge challenges which includes costing lives and investments lost. This can be tied down to several factors. Inadequate collaboration between the construction and design team can be detrimental not only to achieving set goals and client satisfaction but can also lead to loss of lives. In Nigeria, a committee was set up in August 2017 by the Federal Ministry of Power, Works and Housing (FMPWH) to investigate the collapse of fifty four (54) buildings in the nation from 2012 to 2016 (Nnodim, 2017). While the report is not yet published, early prognosis shows that design management had a crucial role in the incidents. Before this, Ayodeji (2011) noted a series of collapse in the country and examined the causes and effects. This examination and that of many other researchers revealed that building materials were substandard, skills of workers were inadequate and most relevant revelation was defects in design and disconnection between designer and contractor (Oloke *et al.*, 2017; Ayodeji, 2011; Fagbenle and Oluwunmi, 2010). Oloke *et al.*, (2017) developed a framework as a result of these issues and called for series of integrity test at different stages of the building lifecycle which required the collaboration of stakeholders and also requested building have facility managers.

2.5.2.3 Abandoned Buildings

The nation has also seen various forms of difficulties in completion of construction projects over the past few years. In a thorough report by Kontangora in 1993, the FG had 4000 construction projects that were either abandoned or delayed by several years

and would take at least 30 years to complete at the current rate of project execution in the country (Olusegun and Michael, 2011). A report by Muhammad and Adaramola (2015) showed that currently, there were projects in the nation worth over N12 Trillion (£240 Million) that have been abandoned in the nation. The statistics based on the

geopolitical zone shows; there are 15,000 in the south-east; 10,000 in the south-south; 11,000 in the north-west; 5000 in the north-east and 12,000 in the north-central. Ownership of these projects ranged from privately owned businesses/ individuals to the various governmental tiers across the nation. As a result of the series of abandoned buildings in the nation, the country has been left with a serious infrastructures deficit. The issue of abandoned project was plaguing the country so much that various bodies such as the National Assembly, Nigerian Institute of Quantity Surveyors (NIQS) and Nigeria Institute of Building (NIB) either carried out awareness workshops or debated possible solutions (Alao and Jagboro, 2017).

Isibor *et al.,* (2016) investigated the factors that cause building projects to be abandoned, and findings revealed the primary factor was lack of funding or rather engaging in a huge number of project without tying it to the availability of funds. However, in most buildings, improper design, lack of construction and estimate plans were significant contributing factors. Olusegun and Michael, (2011) had similar findings and maintained that abandon buildings in the nation were as a result of poor collaboration with design team and construction but also most importantly, the client. Poor collaboration with these stakeholders leads to faulty designs that were wrongly estimated and lead the contractor to have buildability issues the produce poor outcomes bringing the overall project to a halt.

2.5.2.4 Poor Building Performance

Chan (1995) believed performance is most significantly enhanced if the design and construction teams collaborate from the project inception to the building and finally to handing over to facility managers. The maintenance reflects a crucial phase of the project as primarily can take several man-years of effort to review and transcribe the documents that ensure the building performs as designed (East, 2014). Therefore, it is imperative that designs be adequate, and a myriad of documentation available is easy to access to ease maintenance. In Nigeria, there have been several reporting of buildings/ facility functioning inappropriately or not as designed (Ogwueleka, 2011; Idrus *et al.,* 2010; Aibinu and Odeyinka, 2006). In research evaluating the

performance of contractors in Nigeria, Idrus *et al.*, (2010) were able to highlight that there was a massive gap with the understanding of what the client and contractor referred to as a "*high quality"* facility. Client satisfaction rate was meagre in this **54**

research. Ogwueleka (2011) was able to link poor building quality and performance to five contributing factors; the primary factor was design management. Another factors that affect performance in projects were project planning and control; commitment from participants; communication between stakeholders and lack of innovative concepts.

2.5.2.5 Delays in Project Delivery

Projects are considered to be delayed when their completion timeline is later than projected. The Nigerian construction industry suffered from a series of delays in the construction projects, especially buildings. In a paper aimed at identifying project delays causes, Adebakin and Ipaye, (2016) were able to ascertain that several methods of project delivery and procurement adopted in the industry hindered the timely delivery of projects. Adekunle and Ajibola (2015) call out the fragmented approach that leads to disputes in several phases of procurement, leading to difficulties in the decision-making process causes a series of delays. Aibinu and Odeyinka (2006) created an index of significant factors causing delays in the Nigerian AEC, in the first place was financial difficulties. However, closely followed was design management and specialist trade collaborative issues. It is relevant to note that project delay can be caused by a different number of reasons. Nevertheless, several researchers believe that the primary contributing factor in project delay is poor integration and lack of collaborative practices of stakeholders from the inception to facility management of the construction project (Kog, 2017; Adekunle and Ajibola, 2015; Sunjka and Jacob, 2013).

2.5.2.6 Cost Overrun

Cost overrun as the name implies the simple overrun of cost, which means upon completion, or during the construction of projects, it goes higher than budgeted. Cost overrun remains a global issue, and almost 90% of construction projects are reported to have gone over cost globally (Saidu and Shakantu, 2016). The Nigerian AEC industry over the past few decades has these issues in regards to cost overrun. Mansfield *et al.* (1994) examined the construction project management techniques in Nigeria and noticed that there was a substantial variation in the estimated cost of

construction and the actual cost. It is significant to note that most of these project management approaches that were found to be deficient and directly lead to cost overrun remain unchanged. In an investigation into buildings cost overruns (Saidu and Shakantu, 2017) established that all the buildings reviewed overran in cost by an average of 44.46% and were also 52.4% completed. Several types of research have reportedly stated that cost overrun predominately remains to an issue in the Nigerian AEC industry as a result of various factors ranging from poor designs during the design phase of traditional procurement, poor expertise amongst construction team and poor funding (Saidu and Shakantu, 2016; Malumfashi, 2012; Ogunsemi, 2006). This further reiterates the need for an integrated approach in the Nigerian AEC as the same process used in the ’90s is still widely used in the modern era.

2.5.2.7 Poor Quality of Project Delivery

Quality of construction projects is a worldwide issue and has received the attention of various studies (Okpu, 2013; Dollard and Edwards, 2013; Aibinu, 2008; Kale and Arditi, 2001). It is common in the Nigerian AEC that after completion of a construction project, clients deem the project unsatisfactory, unfit for purpose and below standard. Oyedele *et al.*, (2012) used a percentage rank agreement factor (PRAF) analysis in a study, and the percentage demonstrated that changes in design and low involvement of other professionals were both exactly 78.9%. These two factors scored the highest in the study as the causation of poor quality in project delivery. Aibinu (2008) directly points to these issues as a result of the use of inappropriate procurement strategies that allow construction professionals to neither

integrate nor collaborate. Ikediashi (2014) reaffirms this position and recommends that implementation of Information and Communication Technology (ICT) can improve the quality of work immensely by providing construction professionals with a platform to integrate, thereby improving collaborative practices.

2.5.2.8 Lack of Design Comprehension from Client

Comprehension of construction designs by the client is also an emerging issue in the Nigerian AEC, Agu and Ibe (2015) highlighted in a study that it is repeatedly noticed

that clients change design during construction as-built facilities tend not to represent project objective. The lack of client's impartial representation can be directed towards a miscommunication between the design team and architect and; lack of collaboration between them as well (Norouzi *et al.,* 2017). Oyewobi *et al.* (2011) also reiterates this point and believes this can lead to defective construction and rework.

This section examined issues that have occurred as a result of the adoption of fragmented delivery approaches in the Nigerian AEC. Therefore, it is significant to present a delivery method that will mitigate and/or contain these issues from occurring. These outcomes are highlighted as a result of the literature review. In other to create an integrated delivery approach, that promotes collaborative practices, these issues will be reviewed further. The reason for the review will be to establish if these issues are echoed by the industry experts in the Nigerian AEC.

2.6 Chapter Summary

This chapter began with an introductory section, followed by a section which presents several definitions of procurement in the construction industry. It was established there was no acceptable definition of procurement in construction. However, an acceptable definition that explains the concept of procurement in reference to the study was presented.

Several variants of procurement were examined. Included in the review was some construction procurement methods adopted in the Nigerian AEC industry. The traditional method (DBB) was highlighted as the most regularly used procurement method in the Nigerian industry. The DBB variant is by its nature does have several benefits. However, it also comes with several drawbacks that are evident in the industry. These drawbacks outweigh the benefits, hence hinders productivity. The chapter also reviewed the use of PPP in the Nigerian construction industry for several building projects and highlighted how the construction industry attempted to use the PPP as a solution to most procurement issues but has only brought in more problems during its inception. The use of PPP shows that an effort has been made to improve collaboration in the industry; nevertheless, more work can still be carried out to produce a viable solution. Also, a method of the Direct Labour (DL) is still used as a construction procurement method by clients in the industry who have employed in-

house civil engineers and architects on small projects and minor buildings. Also, within the literature, management contracts were also used in the Nigerian industry on some occasions.

The relevance of a procurement system in realising the success of a construction project was reiterated as it presents an overall framework of the responsibilities and authorities various stakeholders have. With this understood, it reduces conflict of obligations/ interest and guides participants in the process of project delivery.

Located within the literature is that collaborative practices can efficiently improve productivity in new building projects. The link between collaboration and an integrated delivery approach was discussed. It was evident that early involvement of stakeholder during the beginning of the building project will improve collaboration. Also, thirteen (13) indicators of team integration were selected from literature. These indicators are an exemplary idea of integration during the construction of new buildings.

The state of the industry was also highlighted, which showed that a lack of collaboration and improper consideration for construction and design management that can lead to detrimental issues such as abandoned buildings, poor building performance, rework, delays, poor quality, cost overrun and lack of client comprehension thereby affecting productivity not mentioning the loss of lives from collapses of buildings all over the nation. These issues presented a need for a different process in the way projects are executed.

In an era where modern economies have sought various methods of procurement to assist in productivity by enhancing collaborative practices amongst stakeholders, the Nigerian industry insists on using an outdated form of procurement on most projects and not achieving desired outcomes.

The next chapter discusses the potential of a BIM-enabled procurement process that can potentially create a collaborative environment during design and construction and subsequent lifecycles either in an assisting role in current procurement or on its own as a bespoke procurement process.

3

Building Information Modelling and its Application in the Nigerian AEC Industry

3.1 Introduction

The aim of this chapter of the thesis defines BIM in general terms and investigates what the meaning of BIM is for this research. It also points out the applications of BIM, the maturity levels and most importantly, the consideration and requirements to adopt BIM. An examination of the global adoption of BIM is also highlighted and examples of some nations' adoption techniques presented. It finally studies the current status of BIM in Nigeria, available researches carried out on the topic, barriers affecting the adoption and finally summarised the findings.

3.2 Building Information Modelling Definitions

This study examined definitions of BIM not just for explorative purposes but to also to comprehend its ability to be introduced in the procurement process to assist in creating an integrated approach during the construction projects in the Nigerian AEC industry, in new building mainly and most significantly assist in enhancing project performance. Table 3.1 presents the various definitions of BIM and their authors.

Table 3. 1 Definitions of BIM

Source	Definition

Penttilä (2006)	*data in digital format throughout the life cycle of a building."*
Ahmad (2013)	*"The process of using information technology for the life cycle of a building through analysis, evaluation, sharing, modelling, collaboration, operation, and management of a virtual building model."*
"BIM acts as a set of interacting policies, procedures, and technologies that generates a methodology to manage the essential building design and project	
Smith (2013)	*"A multi-dimensional and prominent collaborative tool and process, Building Information Modelling is a virtual prototype of the building that supports the AEC projects from design through maintenance."*
HM Government, (2012)	*digital format throughout the building's lifecycle."*
Eastman *et al.* (2008)	*"Integration of corporate strategy, management, computer systems, and information technology throughout the project's entire lifecycle and across different business functions."*
Succar (2009)	
Jung and Gibson, (1999)	
"A collaborative way of working, underpinned by the digital technologies which unlock more efficient methods of designing, creating and maintaining our assets."	
"BIM is an intelligent simulation of architecture that enables integrated delivery achievement."	
"A set of interacting policies, processes, and technologies generating a methodology to manage the essential building design and project data in	

60	*of technical aspects such as 3D modelling, engineering, design, project management and dimensions with the social impact such as process re-engineering." "BIM is a process of designing, constructing or operating a building or infrastructure asset using electronic object-oriented information."*
Autodesk (2002)	
Sackey *et al.* (2015)	
British Standards Institution (BSI), (2013)	*"BIM encompasses 3D parametric modelling of buildings for design and detailing along with a computer-intelligible exchange of building information not only between project stakeholders but also project lifecycle stages."*
Sacks *et al.* (2010)	*"BIM is a process information technology in the building industry that facilitate the creation and operation, management and collaboration for a digital database to be captured, preserved and used for building construction."*
	"BIM is a socio-technical system made up

Table 3. 2 Definitions of BIM

The definition of BIM is comprehended in several ways by different individuals (Eastman *et al.*, 2011). Therefore, a generalisable description of BIM which is accepted universally does not exist. The development of BIM over several years has thus resulted in various interpretations. These definitions range from it being modelling tools, to even being a construction management technique. For this research, the following have been highlighted because of their relevance:

- The ability of the process to manage data about the project from inception to its refurbishment, scrapping, or demolition.
- Most importantly to efficiently create an integrated approach thereby enhancing collaboration and making provision for communication on a single platform

BIM, in particular, offers an opportunity for a paradigm shift in collaboration and construction work practices (CURT, 2004). Also by the smooth transfer of information from one project cycle to another, BIM creates open communication using a single data source (Lea *et al.*, 2015) and limiting the risk when design changes as the project advances. These abilities which BIM exhibits make it an excellent platform to assist collaboration in project performance of new buildings. The ability to create this

platform is useful because the project performance of a new building is an iterative process with various organisations that affect the holistic lifecycle of the building including facility management (FM) phase and demolition. The overall perception is the consistent shift in the global AEC industry to all-around information concerning the construction project and information of that can be stored on a platform online, distributed and accessed by stakeholders. Subsequent improvements involve distributing project data past the procurement and buildability phase towards allowing lifecycle management and controlling in-built structure generating savings and several advantages (Baddeley and Chang, 2015).

BIM can be utilised through various modelling software programmes and does not require all the users to apply the same application. Table 3.2 presents some of these commercial programmes and outlines the use of the tools. It is also relevant to note that there are several other tools through which BIM can be utilised.

Table 3. 3: Some BIM Technology Developers and Software (Bayyari, 2015; Ashurt, 2012)

TOOL	**Developers and Software**
Authoring	• *"4MSA FineHVAC + FineLIFT + FineELEC+ FineSANI"* • *"Autodesk Revit"* • *"Bentley"* • *"CADMEP (CADduct/ CADmech)"* • *"Cype CAD"* • *"Gehry Technologies Digital Project"* • *"Graphisoft Archicad"* • *"Nemetschek Allplan"* • *"Tekla Structures"*
Construction Analysis and Estimating	• *"Autodesk Navisworks"* • *"Solibri Model Checker"* • *"Synchro Professional"* • *"Tekla BIMSight"* • *"Vico Office Suite"* • *"Exactal Cost X"*
Sustainability	• *"Autodesk Ecotect Analysis"* • *"Autodesk Green Building Studio"* • *"Bentley Hevacomp"* • *"Graphisoft EcoDesigner"* • *"IES Solution Virtual Environment VE-Pro"*
Facility Management	• *"Bentley Facilities"* • *"EcoDomus"* • *"FM: Systems FM: Interact"* • *"Onuma System"* • *"Vinotoncon ArchiFM"*

3.3 Applications and Benefits of BIM

The BIM software proffers a wide range of applications and these are usually measured in "*dimensions".* BIM dimensions (D) typically are misunderstood as the *"level of detail or level of development"* (McPartland, 2017). However, the ideas of 2D, 3D, 4D, 5D, 6D, and 7D were developed to represents the elements and advantages of a progressively multifaceted BIM processes.

- **Drafting (2D):** The first potential of BIM is to assist in the design process. 2D BIM is usually a simple draft in the regular 2D format required for the traditional project. The draft can also be viewed as a 3D drawing if reverted to that format but 2D BIM lack all other element and function as a complete 3D model offer.
- **Collaborative Working, Clash Detection, Design, Visualisation and Modelling (3D):** Despite the ability to create building drafts and designs, it also offers a collaborative setting where involved stakeholders input their ideas. 3D proffers these benefits; this is an aspect of BIM is referred to as the glue that holds the construction and design of the project together, as described by Gupta (2014). BIMTalk (2014), highlights significant benefits of 3D BIM, which are project visualisation, clash detection, virtual mock-up models, and prefabrication. This specific dimension enables involved individuals or organisations locate and address issues using the model which leads to the enhanced visualisation of the construction venture, exchange of information regarding design resolutions, promote an integrated approach improving collaboration and reducing reconstruction of defective parts (Impararia, 2014). Azhar (2011) highlighted that BIM was used in a construction project where the appointed contractor is involved early to collaboratively develop MEP, architectural and structural designs of the planned project. The use of BIM led to the detection of more than 55 clashes, saved 1,143 hours, had cost-benefit of over £120,000 and cost 0.2% of the project to set up the model.
- **Scheduling (4D):** The 4D version of BIM is usually synonymous with time and schedule. This dimension offers application like the project phasing simulations, lean scheduling and visual validation for payment approval. BIMTalk (2014) is of the opinion that the two advantages in this dimension

are construction planning and management and schedule visualisation. Koo and Fischer (2000) conducted practicability analyse to highlight the benefits of using 4D BIM model to develop a schedule in a commercial project and

compared it to other methods like Gantt charts and critical path method (CPM) network. This research highlighted that the 4D model was able to recognise the inadequacy of the schedule, discover irregularities through the model and highlight construction sequences and activities that were deemed impossible.

- **Cost Estimation (5D):** The use of BIM can assist in determining the total cost of the construction project and can as details as pointing out specific areas and outlining an estimation. 5D primarily concerns itself with estimates, the dimension also contains information that permits the construction team to precisely and quickly produce a considerable amount of relevant information relating to estimates like the bill of quantity of a material, cost-saving projections to improve productivity, all of which can be adjusted in an automated format when changes are made (Mohandesa *et al.*, 2014).
- **Sustainability (6D):** BIM deals with the sustainability of the project as it helps perform energy consumption analysis. The process takes it one step further and adds information on the expected lifespan and maintenance requirements is regarded as 6D BIM. The data can include details concerning the components manufacturer when it was installed and how to operate it at its optimum level to enhance performance or conserve energy and its expected lifespan.

  Impararia (2014) is of the opinion that earlier in the design process, BIM accurately carries out energy estimates and is very beneficial as this leads to an overall reduction in energy consumption during the operational phase.
- **Facility Management (FM) (7D):** The facility management team requires dependable and accurate data to maintain the facility efficiently (Alreshidi, 2015). This statement makes the facility management a critical stage of the construction project as it is essential the buildings function as designed. Traditional approach projects primarily have loads of handover documents passed down to facility managers by the contractor and can take many working-years of effort to review and transcribe these documents (East, 2014). 7D makes provision for secured handover as (Storer, 2012) highlights that BIM has an additional way to harness more information that the facility team needs

for smooth operations and maintenance requirements. Construction Operation Building Information Exchange (COBie) is a *"non-proprietary data format for the publication of a subset of BIM focused on delivering asset data as distinct from geometric information"* is used at this stage of the facility. Impararia

(2014) states that the integration of BIM with 7D programmes optimises assets management from inception to end life. Wang *et al.,* (2013) believe BIM consists of all the graphics and semantic data of an asset during design and detailing which assists the progress of the exchange of information concerning the facility between the design, construction and operational phase. The transfer allows optimisation and a reduction in the lifecycle cost of the facility.

These benefits are evident, but identifying areas for BIM application is a crucial step in ensuring it is implemented successfully. Ahn, Kwak, and Suk, (2015) in a meticulous study on assisting contractors in adopt BIM suggestion the division the process in five stages. These stages are conceptual planning, design, construction, operation and demolition. However, for the purpose of this study, demolition and operation are lumped together as these are both considered post-construction. The application of BIM during these phases and benefits gained from implementing it are further discussed.

3.3.1 Application and Benefits at the Conceptual Planning Phase

The planning phase is also known as the feasibility phase, during which several benefits of BIM can be applied. Improved visualisation of the building plan can lead directly to the improved decision-making process (Sacks *et al*., 2010; Eastman *et al.*, 2008). Furthermore, benefits such as site analysis, modelling existing conditions and phase planning are benefits which assist involved stakeholders at this phase to collaborate effectively (Ahn *et al.,* 2015).

3.3.2 Application and Benefits at the Design Phase

BIM has several benefits during the design phase of a building that can be applied to assist involved individuals in collaborating. As previously mentioned, improved visualisation is another benefit utilised during this phase. Aranda-Mena, *et al.,* (2009) through benefits such as constructability/ buildability the involved team can make decisions. Moreover, Wu and Issa (2014) highlight benefits such as energy simulation and design optimisation analysis can be achieved. Furthermore, an improved

collaboration that leads the design and construction working together to reduce design error can also be attained implementing BIM (Bolpagni, 2013; Khanzode *et al.,* 2008). Clash detection is another benefit of BIM that can be applied in this phase to enhance collaborative behaviours (Azhar, 2011).

3.3.3 Application and Benefits at the Construction Phase

The construction phase has several benefits that either improve collaboration or reduce building project time, cost and increase quality. Some of these issues were highlighted in session 2.5.2. Benefits such as enhanced construction process, improved communication, cost-benefit analysis, phase planning, reduced conflict among stakeholder, etc. are factors BIM implementation provides to assist collaborative working (Jones and Bernstein, 2014; Dossick and Neff, 2010 Aranda-Mena *et al.*, 2009; Eastman et al., 2008). Furthermore, according to Olatunji *et al.,* (2016) and Bolpagni, (2013) BIM can be used to reduce claims or litigations Ahn *et al.,* (2015) also points out it can assist during site logistics. These benefits combined not only support collaboration but aid in several issues encountered during construction.

3.3.4 Application and Benefits at the Operational Phase

The operational phase is an area that has lately been given more attention; this is because buildings designed to certain specifications repeatedly fail to perform as expected. This presents an issue BIM can directly resolve when used. For instance, BIM can be used as a facility management tool, as highlighted in 3.3; some of the benefits utilised are improved maintenance, increase efficiency and profitability (Ahn *et al.,* 2015). Furthermore, benefits such as waste management, provision of enhanced safety and maintenance scheduling (Khanzode et al., 2008; Ku and Mills, 2008). Finally, after the completion of a new building, a typical handover consists of several documentations from the contractors to the facility owners/ managers. However, with BIM providing a collaborative platform, easy handover of the document on the central platform (Ahn *et al.,* 2015; Khanzode *et al.,* 2008) becomes a benefit that has been be attained at that stage.

3.4 Levels of BIM Maturity

BIM is a management process that has various beneficial levels and dimensions; it is vital to have an understanding about some of these packages and recognise how they can be of use in handling the many problems confronted in the construction industry. Figure 3.1 illustrates the different BIM maturity levels, formats and the tools and capabilities.

Figure 3. 1 Illustration of BIM Maturity Levels (Lin, Roithmayr, and Chiu, 2015)

Lymath, (2014), believes that BIM maturity levels start from 0 to 3 and they determine the progress of basic 2D design to fully integrated collaborative working with the use of distinct and definite stages and further mentions that the definitions of these various levels are always debatable. The different BIM levels are depicted in Table 2.

Recently, there has been a notable extension of what is considered BIM level 2 and 3 with the emphasis being placed on the sequences and management of the facility. Level 2 includes an additional standardised ordered and regulated information. Once

notable authors Lymath, (2014) and McGough, (2013) agreed on a definition, the following points were identified and applied to define the various levels:

- **Level 0-** This level requires no collaboration and has 2D Computer-Aided Design (CAD) for drafting designs. Also, the exchange of data is through the electronic copy. This format was introduced in the 1990s, as illustrated in Figure 3.1.

- **Level 1-** Level 1 consists of a combination of CAD and 3D, the approach of work and adapt. Electronic exchange of information is conducted through the

utilisation of the Common Data Environment. However, level 1 does not require collaboration amongst different stakeholders as they individually distribute and maintain their information with no integration.

- **Level 2-** Level 2 is similar to level 1 with one notable difference, which involves creating a collaborative process, which allows involved stakeholders to utilise the benefit of the 3D CAD model. The information regarding design is communicated through a shared file format that enables any stakeholder to integrate that data with theirs to conduct interrogative checks on it. The shared file format is an approach of engagement which has been used by the government in the UK for all construction projects in the public sector worth over five (5) million pounds (Wolstenholme *et al.*, 2009). Baddeley and Chang (2015) are of the opinion the legal and institutional restraints make this level the only achievable one in the UK. With the view of developing a model with conclusive data and bespoke to the requirements of stakeholders' need, the British Standard Institution (BSI) released the Publicly Available Specification (PAS) 1192 Part "Specification for information for the capital/delivery phase of construction projects using building information modelling" (Lijing and Zhengpeng, 2008 as cited by (Carbonari, Stravoravdis, and Gausden, 2015). PAS 1192 regulates a set of protocols required to meet the Level 2 BIM during utilisation for newly constructed and refurbished construction project. The protocol also ensures collaborative practices are conducted**.**

- **Level 3-** Level 3 is the integrated approach with all stakeholders using a model that is equally shared and kept within the CDE. All the stakeholders

on the project have access and can make modifications to that particular model, eliminating information that can be deemed conflicting. CDE is also referred to as "open BIM", and there were implementation plans for 2018 in public projects, (HM Government, 2012). However, these plans are yet to materialise. Saxon (2013) highlights that this is where design-build teams will need to be integrated from the start, interoperable models will be shared in the cloud and insurance will cover the whole project, protecting the client and team far better.

3.5 The Integration of BIM in the Strategic Definition Stage

The use of BIM presents one main advantage over other process and collaborative tool because of the platform to continue management in new buildings until the end of life. Understanding what stage to in a new building phase to incorporate BIM is the cornerstone for improving the satisfaction of the client. The division of construction projects is customarily carried out by project managers or certified organisations to provide better management control, and these divided phases are known as project lifecycle (Patel and Morris, 1999). The introduction of the concept of project life cycles which has evolved over the decade and seen the various frameworks designed to enhance clarity during various cycles. Patel and Morris (1999) believe that the lifecycle in construction is primarily a distinguishing factor of projects from non projects. Examining the multiple life cycles of the new building and their expectations can aid in identifying the most crucial stage of the lifecycle of a project.

Table 3. 4: Project Lifecycle of the construction project (Hendrickson, 2008)

Project Lifecycle					
Strategic Definition	Preparation & Brief	Concept Design	Developed Design	Technical Design	Construction Use

The definition of project scope and objectives is the stage when an organisation identifies an opportunity to which it would like to respond and carries out the study on the decision if the project is practical or not (Patel and Morris, 1999). All stages from strategy or definition of project scope and objectives to technical design or design

usually are combined and alluded to as the pre-construction phase, while the construction phase usually is on it is own in the construction industry (Hendrickson, 2008). While in Table 3.3, the maintenance and facility disposal are towards the bottom, Hendrickson (2008), believes that maintenance or use or handover of a facility will go on long after the completion and acceptance of a project, it is usually treated as a separately in some cases. According to Wang *et al.,* (2013), facility management is subdivided into three sections: maintenance and repair, commissioning and handover and energy management. Alexander (2013) defines facility management in construction as a procedure whereby stakeholders guarantee that its facilities, systems and services support core processes and approach as well as contribute to attaining its intended objectives in evolving conditions. East, (2014) believes that after the

construction of a project is completed, handed over and celebrated by occupants, for those responsible for operating and managing that facility, however, the work is just beginning. The work can be challenging as a result of a lack of collaboration from the earlier stages of the building project.

Wang *et al.,* (2013) believes that facility management should be taken into account right from the design stage and develop along with the project because this can reduce efforts for maintenance during the operational phase of the facilities and reduce alterations. Rework in the construction industry occurs during construction as a result of decisions made poorly in the early design phase (Schlueter and Thesseling, 2009) and this rework usually affects significant changes in timeline and cost of the project. These changes which can be very costly may come up to five times larger, depending on the cycle of construction (Doran, Douglas and Pratley, 2009).

These issues lead to increased demand levels of collaboration between involved organisations during preconstruction between the project sponsor, designer, general contractor, project manager, civil engineer, MEP, subcontractor, materials and equipment (Magent *et al.,* 2010; Bresnen *et al.,* 2004). This interaction amongst multidisciplinary suggests that early involvement of participants (Nawi *et al.,* 2014), partner experience and high level of compatibility with project teams results in a better outcome. Therefore, efficiently integrating construction requirements and knowledge at the early stage (strategic definition/ preparation and briefing) of the project lifecycle is imperative and produces general improvement in the performance of the project (Jørgensen and Emmitt, 2009). Therefore, integrating collaborative issues with the use

of BIM ought to be in the strategic definition and briefing phase. The early inclusion will be to allow the nature of the project to reflect in the design phase and subsequent lifecycles.

3.6 BIM Requirements/ Considerations for Efficacious Adoption

To adopt the use of BIM, several researchers, industry specialist and regulatory bodies use a framework to enhance understanding while adopting the technology (Liu *et al.*, 2015; Porwal and Hewage, 2013; Gu and London, 2010; Succar, 2009). Philibert (2011) defines a framework as a holistic system that assists the user in guiding and explaining patterns with clear inputs and outputs. Moreover, the adoption of BIM in the construction involves certain stakeholders from different

fields to collaborate to achieve a productive outcome. Therefore, a need for a framework presents itself when the adoption of BIM is required. Several studies have suggested different requirements and considerations for the adoption and development of BIM. This research considers Succar (2009) and Enegbuma *et al.* (2014) frameworks of adoption. These studies are selected as the researcher believes it best suites the objectives of the study of a Nigerian model when adopting BIM. Figure 3.2 (Enegbuma *et al.,* 2014) and Figure 3.3 (Succar, 2009) presents various stakeholders in the construction industry, BIM perception and requirement for successful uptake of BIM.

Figure 3. 2 Framework for the effective adoption of BIM (Enegbuma *et al.,* 2014) Enegbuma *et al.*, (2014) adopted a system where implementation was from a perspective of linking people, process, and technology and strategic IT in construction to a collaborative process as a result of which BIM is adopted. As displayed in Figure 3.2, the strategic IT in construction has two main factors, which are business process re-engineering and computer integrated construction. Therefore, to successfully consider the adoption of BIM, it is relevant to comprehend in what way or manner these factors can lead to successful adoption.

It is necessary to understand that for the successful adoption of BIM several stakeholders in the construction industry have fundamental responsibilities to perform. This understanding is illustrated through the use of a Venn diagram in Figure 3.3 by pointing out the different stakeholders.

Figure 3. 3 The three major interlocking fields of BIM. 1- Technology advocate; 2- industry associations; 3- Communities of practice; 4- BIM experts

Policy, technology and process stakeholders are described in Figure 3.3 by Succar (2009). These three stakeholders combine to execute different but somewhat similar functions when BIM is adopted. 1, 2, 3 and 4 highlight critical players that crossover from one factor to another as a result of having a common interest in those overlapping factors. According to Succar (2009), the numbered overlapping area means the following:

- 1: The overlap between policy and technology represents "*interoperability standards."*
- 2: The overlap between process and policy represents the need to update skills continually by training and highlights industry associates as the key players in enabling it.
- 3: Process and Technology overlap at this phase and primarily involves *"communities of practitioners"* interested in the same software package and the operationality.

- 4: Finally, where the universe of the Venn diagram is in Figure 3.3 represents a

combination of all the factors and the realisation of BIM implementation requirements and the key player is usually BIM expert(s)/ specialist (s).

After carefully reviewing the two frameworks, five factors were selected for further review to understand the role these factors play in the uptake of BIM. These factors are; Process, People, Policy, Technology and Strategic IT in Construction.

3.6.1 Process and People in the Adoption of BIM

The process is merely undertaking a series of activities to achieve the desired outcome; the area of process incorporates issues involving project delivery. According to Kassem (2015), the process is the procurement aspect of BIM and consist of facility managers, contractors, designers, trade specialists and suppliers. "*BIM Process Player*" as referred to by Kassem, can be a plumber or the construction firm using BIM to achieved project requirements (Kassem, 2015). The process is grouped with people because the process primarily allocates responsibilities for the people (stakeholder) contribute to ensuring BIM use is efficacious. BIM process is only as important as the information the people input in it (Deutsch, 2011) this means these two factors closely associated and can be perceived to be somewhat similar. Davenport (1993) is of the opinion that this factor should have clear inputs, outputs and precise description of the individuals (people) obligations during an activity. Therefore, for the implementation of BIM, there has to be adequate training amongst stakeholders (Akwaah, 2015; Enegbuma *et al.*, 2014). In regards to the process, a new workflow needs to reinvented for the people to understand their duties and obligations when using BIM (Kassem, 2015; Succar, 2009).

3.6.2 Technology and Strategic IT in Construction in the adoption of BIM

The technology and strategic IT factor point out the necessity of technical proficiency to enable the user to comprehend with obligations when adopting the use of BIM. Strategic IT application requires various firms designing strategies that suit their organisation in a manner that incentivises technological approaches and rewards creative problem-solving abilities. Enegbuma *et al.,* (2014) categorises strategic IT into two classifications; Business Process Re-Engineering (BPR) and Computer Integrated Construction (CIC). BPR comes about as a result of making changes in the day to day activity of organisations because of the relationship between the *"business-pull"* and the *"technological-pull"* (Alshawi, 2007). The point is reaffirmed by

Aranda-Mena *et al.* (2009); Chen *et al.*, (2017); East, (2014) with the observed the BPR takes into consideration the business process of the organisation and the structure of BIM technology to allow the appropriate implementation of BIM technology to achieve business objectives. Arayici and Aouad (2005) are of the opinion that CIC requires developing and improving work activities; document templates and; an innovative way to manage the change in the application of the technological process presents.

According to Succar (2009), this factor involves "*interaction between software, hardware, equipment and networking systems to enable or to support the design, construction and operations of structures and facilities*". For the adoption of BIM to be achieved, there also needs to be a technological push from clients (Jordani, 2008) for innovative solutions to issues that plague the construction industry. For the smooth and easy adoption of BIM, there is a need for a readily available technological platform that makes BIM deliverables possible to use. According to the overlap between the technology and policy in Succar's Venn diagram (Figure 3.3) interoperability standards are required for users to be able to combine the model from a different platform through an object library. Moreover, with the overlap between the technology and process, there is a requirement of communities of BIM users improve the object library. Therefore, the technology aspect should consider how its adoption can improve organisations and the effect it has on working activities during the adoption of BIM technology.

3.6.3 Policy in the Adoption of BIM

A policy like most words have multiple definitions and interpretations, but for this research, we use Schopper, Lormard, and Waweiler, (2006) definition as strategic plan or programme that provides the basis for the action of activities within a system. In regards to BIM, this involves governmental agencies creating guidelines for the use of *"protocols and regulatory frameworks"* to assist BIM users with the clarity of responsibilities during the adoption of BIM (Kassem, 2015). Most countries that have been able to use BIM have done so with the use of standards created either at federal, state and even local level. Succar (2009) is of the opinion that the major players in this

field should be governments and research institutions, and the primary deliverable should be best practice and contractual agreements.

It is apparent that the road to the adoption of BIM involves a transparent, collaborative process from several of the AEC stakeholder. This statement is ironical as BIM itself provides a collaborative environment that helps AEC stakeholders integrate on construction projects. It is relevant to note that everyone will have to play their part in the uptake of BIM is to succeed.

3.6.4 Other BIM Adoption Research Framework

Philibert (2011) maintains that for a proposed framework to be able to produce tangible outcomes, it necessary to research and understand the previous frameworks, what solutions they proffered and how the proposed one can be different. It is relevant to comprehend that a copious amount of researchers has either developed different frameworks or adoption/ implementation techniques globally. In comprehending, some of these researchers and identifying limitations in their work enhances the unparalleled outcome of this research. Table 3.4 presents some of the research, the problem the research identified and the resolution of the research derived.

Table 3. 5 Previous Adoption of BIM Implementation Framework Research

Previous BIM Adoption Framework

Source Title Research Problem Proffered Solution

Zanni (2016) *"Communication of Sustainability Information*

moreover, Assessment within

BIM-enabled Collaborative

Environment"

Liu *et al.* (2015) *"A BIM-aided construction waste minimisation framework."*

Buildings ability to sustainably perform remains an issue among stakeholder in the construction industry. The AEC industry has problems where the right information is not always available at the right time. Therefore, problems encountering in achieving sustainable buildings.

The AEC industry currently has insufficient tools for construction waste management (CWM). As a result of which, sustainability becomes an issue on the construction project, and waste occurs.

An IDEF (0 & 3) framework was designed using BIM to assist communication patterns amongst stakeholders in a construction project, thereby achieving collaboration to produce information at the right time throughout the design stage.

Collaboration from design phase determines ease of waste management; a BIM framework was developed and validated at the design stage of construction projects. Therefore, with the use of BIM– enhanced practices, waste can be reduced, and management can also be assisted.

Enegbuma *et al.* (2014)

"Building Information Modelling Penetration Factors in Malaysia"

With Malaysia slowly accepting the concept of BIM adoption in the nation, this research was aiming to understand how BIM can efficiently be used in the country.
Enegbuma *et al.* (2014) were able to create a penetration model that BIM users in Malaysia could use when soliciting the benefits of BIM for construction projects. The framework will be able to assist BIM implementation in the nation and aid in the challenges experienced by practitioners.

Kapogiannis (2013) *"A Conceptual Framework for Project Managers to Improve Project Performance"*
Projects in the construction industry often encounter issues in regard to satisfactory project performance.
This research created a conceptual framework that used BIM to create a collaborative environment, thereby encouraging proactive team behaviour. The impact of proactive behaviour was improved project performance.

Abrishami *et al.* (2014)
"Integration of BIM and Generative Design to Exploit AEC Conceptual Design Innovation"
The knowledge gap identified in this research highlighted issues concerning mechanisms needed to efficiently carry out computational design methods using BIM during the design stage.

A framework was developed using an algorithm to allow the engagement of generative design methods into a single BIM platform. This algorithm allowed the creation of several models and ranked them accordingly, allowing the designer to choose which best fit the purpose.