Digital Prototype Framework for Understanding Building Information Modelling Adoption:
Nigerian Small and Medium Architectural Firms

A Thesis Submitted in Partial Fulfilment of the Requirements of
Salford University for the Degree of Doctor of Philosophy

April 2022

USMAN UMAR MAKARFI

UNIVERSITY OF SALFORD
School of Science Engineering and Environment

Table of Contents

List of Figures

List of Tables

Acknowledgments

Firstly, I would like to thank the Almighty for granting me this priceless opportunity to further my studies through a research degree. I would like to express my gratitude and sincere acknowledge to these two great personalities - Prof Jason Underwood and Prof Chika Udeaja - for their valuable support, mentorship, advice and words of encouragement at key times during this study. They have always guided me with affection and encouragement while ignoring my shortcomings. Their in-depth knowledge, broad experience, commitment and confidence in me have been a source of constant motivation during this long and tedious process. I also owe deep gratitude to my loving parents who always showered me with their love, guidance, support, encouragement, and prayers. I am sure you will both be proud of my accomplishments. My gratitude also goes to my dear wife, Hauwa'u, who was always by my side during this entire process and supported me during the difficult times. My loving thanks are also due to my two little ones, Aisha and Sa'adah, for always cheering me up and filling my heart with happiness. I would also like to thank all my siblings for their prayers over the years and my mother-in-law for her continuous support. Sincere appreciation also goes to my colleagues, and friends, past and present. You have helped, encouraged, cheered or even scolded me from time to time and your acquaintance has given me a rich and rewarding experience as a PhD student. My special thanks also goes to Dr. Sa'id Kori who mentored me from the very beginning and Dr. Uche Ogbonda who constantly inspired me academically and personally.

Finally, I would like to acknowledge the financial support from the Petroleum Technology Development Fund (PTDF), Nigeria.

Declaration

I declare that the research contained in this thesis was carried out by me. This work has not been previously submitted either in part or full for any other award than the degree of Doctor of Philosophy in the Built Environment at the University of Salford.

Dedication

To my dad, who is not with us today to witness the fruit of my labours.

Abstract

Globally, Building Information Modelling (BIM) has solidified its position in bringing efficiency to the construction industry. However, the shift to its adoption and implementation in emerging markets such as Nigeria has brought distortion to both the business processes and the environment of Small and Medium Architectural Firms (SMAFs) in the construction industry. This is due to their limited understanding of the BIM adoption process and their limited resources to absorb the costs associated with such a shift. Therefore, it is important to understand the BIM adoption process and the key factors that influence this within Nigerian SMAFs in order to understand where to focus their limited resource. Thus, this research seeks to develop a framework to understand the BIM adoption process within Nigerian SMAFs. To achieve this, a three-step process was designed, namely: a theoretical phase, empirical phase and framework phase.

Firstly, the theoretical phase was based on a review of extant literature, the formulation of theory and its conceptualisation. In the theoretical phase, the current state-of-art of the Nigerian construction industry (NCI) and BIM were explored. This was crucial in identifying the factors that influence BIM adoption within SMAFs, and in understanding the theories that revolve around the subject area. As a result, the study utilised and built upon the theories, frameworks and models related to BIM to conceptualise the factors identified and develop a conceptual framework. Thus, four distinct key factor categories that influence BIM adoption success within the SMAFs emerged, namely: organisational compatibility, individual competence, environmental control, and technology quality.

Secondly, the empirical phase comprised of the data collection, analysis and synthesis. In this phase, the empirical enquiry or fieldwork was conducted, which provided empirical evidence of the relationship between the key factors and BIM adoption success within the context of Nigerian SMAFs. The data collection was conducted through a sequential mixed method combining both quantitative (questionnaire survey) and qualitative study (semi-structured interviews) with professionals from Nigerian SMAFs.

Finally, the framework phase, consisted of the framework development, prototype development and the validation. It was achieved by synthesizing the findings based on the results and analysis of both the theoretical and empirical phases. However, to establish the priorities of the identified categories and their associated factors, the Analytic Hierarchical Process (AHP) method was employed. The framework was further utilised to develop a digital prototype application, which has both mobile and web-based versions. The developed framework was validated through a small-scale interview with experts based on criteria such as comprehensiveness, usefulness, feasibility and generality.

Fundamentally, there are two contributions of this study to the existing body of knowledge: (i) the theoretical contribution is demonstrated by providing empirical evidence that establishes the relationship between key factors, which have been clustered into four main categories (i.e. organisational capability, individual competence, environmental control, and technology quality) and the BIM adoption process within Nigerian SMAFs; and (ii) the practical contribution is evidenced by developing a digital prototype of the framework to facilitate an understanding of BIM adoption process amongst Nigerian SMAFs and inform their decision-making on how and where to invest their resources.

1 Chapter One – Introduction

1.1 Chapter Overview

This chapter introduces the research by providing the context and background. The chapter provides a rationale for the study and highlights the research aim and objectives. Additionally, in this chapter, the scope and boundary of this research are defined and justified. Furthermore, a general overview of the research process and the organisation and structure of the thesis are presented. The following section commences by presenting the research background.

1.2 Research Background

Although the construction industry possesses a unique status in the development of a nation's economy, it has been continually criticised for its poor performance, inefficiency and structural fragmentation in numerous industry and government reports (Egan, 2002; Farmer, 2016; Latham, 1994; Simon, 1944). In Africa, Nigeria is the largest economy and the 27th largest in the world (World Bank, 2018). The Nigerian construction industry (NCI) contributes significantly to the GDP of the nation; for example, although the recent global pandemic harmed the economy and construction activities, the Nigerian construction industry's contribution to GDP was approximate 3.19% in the second quarter of 2021 (National Bureau of Statistics, 2021). Nonetheless, similar to the global construction industry, the NCI is criticised for its lack of productivity and inefficiency due to its fragmented nature (Abubakar et al., 2014). The fragmented nature of the NCI has brought about several challenges within the industry, including delays in project delivery (Egwim et al., 2021), cost and time overruns (Saidu & Shakantu, 2017b), the occurrence of rework (Bon-Gang et al., 2019), collapse and fatalities (Alaneme et al., 2021; Oloke et al., 2017), and the abandonment of projects (Adebisi et al., 2020; Alao & Jagboro, 2017) among others. Consequently, efforts made to address criticisms of the global construction industry range from new contractual/procurement arrangements like partnering, concurrent engineering, and integrated project delivery (Ahmad et al., 2006; Kim & Dossick, 2011) to technological innovations in design and construction processes such as 3D CAD and modelling (Underwood & Isikdag, 2011). However, among such innovative processes that promise to bring about continuous improvement and enable the desired transformational digital change in the construction industry is Building Information Modelling (BIM).

Building Information Modelling has various definitions, although it is considered a process of creating and managing information on a construction project across the project life cycle using a digital model containing graphical and non-graphical information or data (Hamil, 2021). As such, it serves as a shared knowledge resource for information about an asset forming a reliable basis for decisions during its life cycle from inception onward (Arayici, Coates, Koskela, Kagioglou, Usher, & O'Reilly, 2011; BSI, 2019). Some of the benefits of BIM technologies, as claimed by its proponents, are that it provides for efficient communication and data exchange (R. Liu et al., 2017), auto quantification, improved collaboration, the coordination of construction documents, the enhanced visualisation of design (Sacks, Kedar, et al., 2018; Sher et al., 2010), clash detection and cost reduction (Eastman et al., 2012) among others. Furthermore, Liu et al. (2017), Underwood & Isikdag (2011) and Wong et al. (2015) documented substantial evidence of construction project delivery improvements within countries such as the USA, UK, Australia, Netherlands, Singapore, Hong Kong, Finland, Norway, Denmark and Hong Kong which have adopted BIM at various project levels.

1.3 Research Rationale

The critical issues of construction revolve around maximising value, increasing safety, and reducing cost, especially since the criticism of the industry for its lack of productivity and inefficiency (Egan, 2002; Farmer, 2016; Latham, 1994; Simon, 1944). Traditionally, 2D drawings and documents have been used to develop, design and manage project information; this practice has led to misunderstanding and human error due to the misinterpretation of design and engineering documents (Sönmez, 2018). This adds a layer of functional design information requirements, further complicating the design and delivery process (Cohen, 2010). However, BIM is seen as an important paradigm shift in the construction industry because it necessitates an alteration in the processes and current culture to achieve a more integrated approach (Hannele et al., 2012; Khosrowshahi, 2017; Succar, 2009). Therefore, the nature of BIM requires firms to do things in a new way, and it is challenging to come up with a single BIM adoption model for the construction industry. Thus, to fully adopt BIM, elements such as technology, process, policy and people have to be considered (Succar et al., 2012).

Furthermore, developing a BIM model requires collaboration between design professions such as architects and engineers (Ardani et al., 2021). For example, the initial building design elements are created by the architect, then other engineering elements are added to the model by the engineers (structural, mechanical and electrical), and subsequently other professionals such as contractors add their elements to the BIM model. In the Nigerian market, architects are responsible for developing the BIM model and in most cases bear the cost of changes in the model during construction, as clients are not willing to pay for extra expense (Onungwa &

Uduma-Olugu, 2017). Therefore, this indicates that architects are usually the creators of the initial BIM model and should be at the forefront of BIM adoption. Similarly, in the US, architects originally lead BIM adoption prior to government intervention (Hamma-adama et al., 2018).

Hamma-adama et al., (2018) reported that, in relation to BIM in Nigeria, there are traces of “lonely BIM” adoption at the organisational level as only a few architects utilise the tools for the visualisation and presentation of drawings, while structural and services design are still undertaken conventionally using 2D CAD. However, according to Kori & Kiviniemi (2015), Nigerian small and medium architectural firms (SMAFs) predominantly adopt the technology aspect of BIM while neglecting other aspects such as process and policy (practical implementation gap). This is often associated with the lack of a clear understanding of the BIM adoption process (theoretical gap), hence making it challenging to fully adopt BIM at the organisational level. Against this backdrop, Figure 1.1 illustrates the research rationale by highlighting the practical and theoretical gaps of BIM adoption within Nigerian SMAFs.

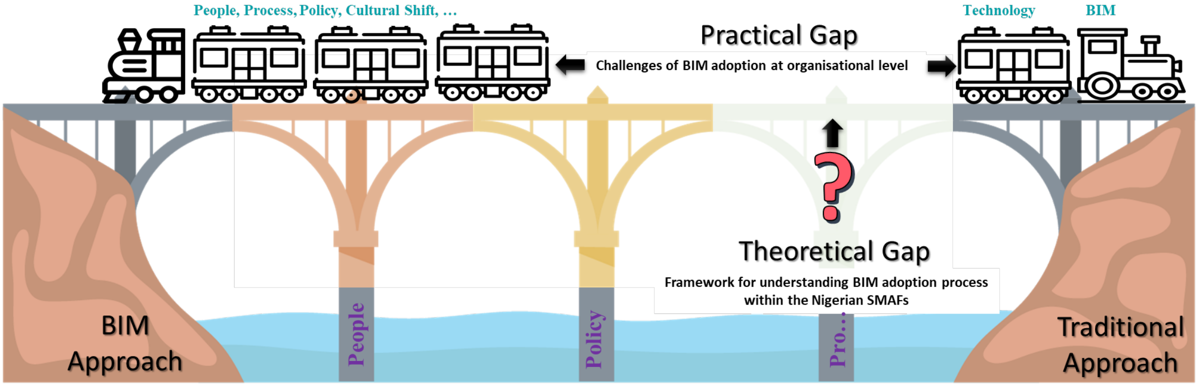


Figure 1.1: Research Rationale Diagram

Despite the documented benefits and potential for BIM to alleviate or mitigate the challenges of the Nigerian construction industry (Hamma-adama et al., 2018), BIM adoption within the industry is still lagging, particularly within Nigerian SMAFs (Adekunle et al., 2021). Nigerian SMAFs find it challenging to transition from the traditional to the BIM approach due to the practical challenges of implementation at the organisational level (Kori & Kiviniemi, 2015; Makarfi & Kori, 2018). Among the organisational challenges are a lack of clear guidance on how to fully adopt BIM (i.e. not just the technical aspect without the associated processes and policies) and limited available resources to invest in BIM adoption (i.e. financial resources to improve the firm’s capability). Thus, the organisational challenges of BIM implementation/adoption have lead to the emergence of frameworks to facilitate the BIM adoption process.

Globally, the efforts made towards developing frameworks to improve BIM adoption are mostly not explicitly developed for the Nigerian context. For example, Hosseini et al. (2016) focused on the Australian context, Son et al. (2015) focused on Korea, Ahuja et al. (2020) on the Indian market, and Qin et al. (2020) on China. Moreover, the research on BIM adoption in Nigeria is often limited to identifying the drivers (Saka et al., 2020), barriers (S. Babatunde, Udeaja, et al., 2020), training (Onososen & Adeyemo, 2020) and critical success factors (Amuda-Yusuf, 2018) as opposed to providing an understanding of how the critical success factors, drivers, barriers and training contribute to the practical implementation and adoption process of BIM within the Nigerian context. Therefore, considering the literature available and the challenging situation within Nigerian SMAFs, this study aims to bridge the theoretical gap by developing a framework to understand the BIM adoption process within Nigerian SMAFs. A thorough understanding of the framework will help professionals and practitioners within Nigerian SMAFs to understand (i) the process of BIM adoption, (ii) the factors that influence BIM adoption, and (iii) the relationship between the factors and BIM adoption process. This, in turn, will enable Nigerian SMAFs to make informed decisions on where to allocate their limited resources and contribute towards taking effective measures to facilitate the adoption of BIM within their firms. In this regard, the research questions associated with this study are as follows:

1. How can the BIM adoption process be analysed and understood to improve BIM adoption within Nigerian SMAFs?
2. What are the key factors that influence BIM adoption within Nigerian SMAFs?
3. To what extent do these key factors influence the BIM adoption process within Nigerian SMAFs, i.e. the priorities and relationships of the key factors to the BIM adoption process?

1.4 Research Aim and Objectives

This research aims to develop a framework for understanding the Building Information Modelling adoption process within Nigerian Small and Medium Architectural Firms. To achieve this aim, the following objectives are outlined:

1. *To determine the current state of the art of the Nigerian construction industry and BIM.*
2. *To identify the key factors that influence BIM adoption within Nigerian SMAFs.*
3. *To develop a conceptual model through the identified factors that influence BIM adoption within Nigerian SMAFs.*
4. *To establish the relationships between the factors that influence BIM adoption and the adoption process within Nigerian SMAFs.*
5. *To develop a digital framework for understanding the BIM adoption process within Nigerian SMAFs.*
6. *To validate and propose a final framework that best describes the BIM adoption process within Nigerian SMAFs.*

1.5 Research Scope and Boundary

Many segments, sectors, and disciplines in the construction industry have their practices, characteristics, and systems. Therefore, it is reasonable to define the scope and boundary of the research. In addition, BIM could be adopted or implemented at a different level or scale. For example, Kouch (2018) argues that three BIM adoption/implementation levels are individual/project, organisation, and market/nationwide. Moreover, it is unrealistic to focus on BIM adoption at all the levels in this study due to the limited timeframe and resources available. Thus, this research primarily focuses on BIM adoption at the organisational level (i.e. Nigerian SMAFs). Similar to the US, where architects lead BIM adoption before any government intervention (Hamma-adama et al., 2018), in the Nigerian context, the BIM model is also initially created by architects (Onungwa & Uduma-Olugu, 2017). Therefore, within the organisational level, this research focuses on architects rather than on all construction professionals. In the context of this research, the term "SMAFs" is defined as any small and medium architectural firm whose number of employees total 250 or less (Kori & Kiviniemi, 2015; Adedapo Adewumi Oluwatayo, 2009). The research concentrates on SMAFs for two main reasons: (i) SMEs are the backbone of the Nigerian construction industry and are often on the disadvantaged side of the digital divide in the industry, particularly BIM (Saka et al., 2020). According to Saka & Chan (2021), SMEs within the NCI face slow BIM adoption uptake. (ii) SMEs have limited resources (S. Babatunde, Udeaja, et al., 2020) and therefore, it is essential to prioritise their resource allocation through effective decision making. (iii) To gather information about SMAFs, this study considers only firms led by architects listed in the Architectural Registration Council of Nigeria (ARCON, 2017). Thus, having discussed the scope and boundary of the research, the subsequent section presents the overview of the research process.

1.6 Overview of Research Process

The research philosophy adopted by this research study is pragmatism. A quantitative inquiry and qualitative study research method that accord with pragmatism are applied. This study includes elements of both theory-testing and theory-building; the theory-testing element involves testing the conceptual, theoretical list of factors, while theory-building involves the incorporation of new, additional findings to the previously built, conceptual, theoretical list in order to revise it. The data collection methods are questionnaire surveys and interviews with experienced professionals from Nigerian SMAFs.

Firstly, a three-step research design is adopted to simplify the research process, as shown in Figure 1.2. These stages include the theoretical stage (literature review, theory formulation, conceptualisation), empirical stage (data collection, data analysis, data synthesis), and framework stage (framework development, prototype development, framework validation). In the first stage - the theoretical formulation - a literature review was conducted to understand the Nigerian construction industry's current state of the art BIM adoption. This stage identifies the factors that influence BIM adoption within Nigerian SMAFs and the development of the conceptual model. The conceptual model assisted in the empirical evaluation of the factors identified to influence BIM adoption within Nigerian SMAFs.

The empirical inquiry, data collection, analysis, and synthesis were conducted during the second stage. This stage was essential in validating the conceptual model and providing empirical evidence for this research. The empirical evidence was instrumental in establishing the relationship between the key factors (i.e., constructs) and the BIM adoption process within Nigerian SMAFs. The third and final (Framework Development) stage entailed the development of the framework, digital prototype, and validation of the framework. The proposed framework was developed by establishing the hierarchy/priority of the factors influencing the BIM adoption process within Nigerian SMAFs. The priorities were evaluated using the Analytic Hierarchical Process AHP method, while the validation was carried out through small-scale semi-structured interviews with experts on the subject matter. Finally, the digital prototype was presented as a web-based application and a mobile application to ease the accessibility and improve the user experience.

1.7 Thesis Organisation and Structure

The structure of this research followed the process of the research, as shown in Figure 1.2. From Figure 1.2*, three essential components make up the research structure diagram:* the research objectives, the research process, and the thesis chapters. The depiction of the relationship between the objectives and process shows that, the theoretical phase of this research addressed objectives one, two and three. Subsequently, the empirical phase addressed objective four, and lastly, the framework phase addressed objectives five and six.

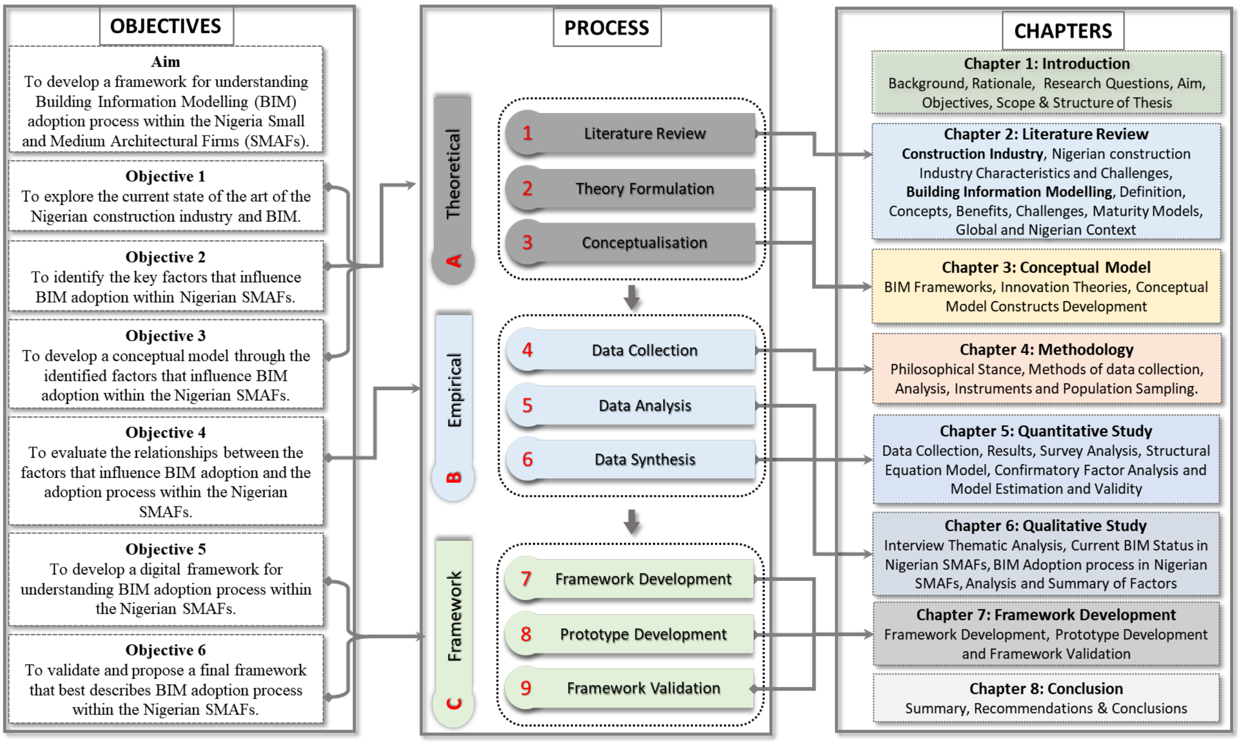


Figure 1.2: Research Structure Diagram

This thesis contains eight chapters, which are presented logically based on the research process and progress, and each chapter links to the next. At the beginning of each chapter, an overview of what the chapter entails is presented to give the reader the highlights as to what to expect. Following a similar pattern, a summary of what has been discussed is presented at the end of each chapter, also highlighting what the subsequent chapter will entail. Having clarified the chapter organisation, the chapter structure is as follows:

Chapter One: Introduction

This is the introductory chapter that provides a general overview of the research. In this chapter, the background of the study, the rationale/ justification, aim and objectives, scope and boundary, an overview of the methodology and thesis structure have been presented to guide the reader.

Chapter Two: Literature Review

This chapter entails the critical review of extant literature related to the construction industry and BIM adoption. This chapter explores the current state of the art of the Nigerian construction industry and BIM (objective one). The key areas to be discussed are the NCI's characteristics and challenges, the concept of BIM, definition, benefits, drivers, barriers, and BIM adoption status (partially addressing objective two). The literature review chapter will provide a basis for the theoretical formulation and conceptualisation of the conceptual model.

Chapter Three: Conceptual Model

This chapter identifies and conceptualises the factors influencing BIM adoption (objective two). The chapter also reviews BIM-related frameworks, theories and models. In this chapter, the conceptual model will be developed by identifying and establishing the various constructs. This chapter provides an insight into the relationship between the variables within the construction models. This chapter will address objective three, which intends to develop a conceptual model by identifying the factors that influence the BIM adoption process within Nigerian SMAFs.

Chapter Four: Methodology

This chapter presents the research methodology for this study by answering three critical questions: (i) what are the philosophical positions of the research; (ii) what are the adopted research methodologies; and (iii) how are the chosen methods to be used in this study? The chapter justifies the selected methodological choices for the empirical enquiry. The chapter will also discuss vital topics such as the philosophical stance, research design, research strategies, techniques and procedure, and ethical issues and considerations.

Chapter Five: Quantitative Study

This chapter presents the analysis and discussion of the quantitative study. The discussion includes the questionnaire design, pilot study, preliminary data analysis, model measurement analysis, model construct estimation, and validity measurement. The quantitative study validated the conceptual model and established empirical evidence of the relationship between the key influencing factors and the BIM adoption process within Nigerian SMAFs.

Chapter Six: Qualitative Study

This chapter presents the analysis, findings, and discussion of the qualitative data. An overview of the current status of BIM within Nigerian SMAFs, the current understanding of BIM, and the benefits and challenges of BIM adoption will be presented. The chapter will elaborate on the factors that influence BIM adoption and establish the relationship between the factors and the adoption process within Nigerian SMAFs (objective four).

Chapter Seven: Framework & Prototype Development and Validation

This chapter initially presents the process of developing the framework by leveraging Chapters Five (quantitative study) and Six (qualitative study). The chapter established the structure of the framework and prototype, before prioritising the factors that influence BIM adoption through the AHP method. The framework developed for understanding the adoption process of BIM within Nigerian SMAFs was further developed into a digital prototype (objective five), which is presented as a web-based application and a mobile application. Finally, the chapter presents the validation process and outcome of the framework (objective six). This chapter addresses objectives five and six.

Chapter Eight: Conclusion

This chapter presents the research conclusion remarks, which summarises the research journey. The chapter also discusses the attainment of the objectives, limitations of the study, and the practical and theoretical contributions of the study. Finally, the chapter presents the recommendations for further research.

1.8 Chapter Summary

This chapter has presented the research background, rationale, aim and objectives, scope and boundary, overview of the research process and outlines of the thesis structure. It has sought to provide an overarching study scene along with a route map describing the research tasks and developmental processes, whilst contextualising the study in order to highlight its added value within the expected boundary. The next chapter will provide a critical review of extant literature with a particular focus on the characteristics and challenges encountered by the Nigerian construction industry and BIM.

2 Chapter Two – Literature Review

2.1 Chapter Overview

This chapter seeks to explore the current state of the art of Nigerian construction industry and Building Information Modelling (BIM) through an extensive review of literature. The chapter will commence with a general overview of the Nigerian construction industry while highlighting its characteristics and challenges. The chapter will then highlight the potential of utilising BIM to mitigate challenges within the construction industry. Additionally, the concept, application, drivers, and barriers to BIM adoption will be presented. Thus, the construction industry is presented in the subsequent section.

2.2 Introducing the Construction Industry

The construction industry in both developed and developing countries is a diverse sector of the national economy and engaged in construction through planning, design, construction, maintenance and repair, and operation to transform various resources into constructed facilities or assets. The public and private facilities produced range from residential and non-residential buildings to massive infrastructure (Kheni et al., 2008). The major participants of the construction industry include architects, engineers, management consultants, general contractors, heavy construction contractors, individual trade contractors or subcontractors, and construction workers, along with the owners, operators, and users of the constructed facility (Clough et al., 2015). Finance and insurance agencies, land developers, real estate brokers, material suppliers, and equipment manufacturers are some of the other construction industry actors considered distinct yet auxiliary to the construction industry (Clough et al., 2015).

Global construction expenditure is expected to exceed $12.4 trillion by 2022 (Newswire, 2018). Over the next ten years, the UK government will spend around £600 billion on public and private infrastructure, increasing the efficiency and productivity of building projects and making it a strategic priority (Neely, 2018). Currently, low productivity is cited as the main cause of failure in the construction industry (Farmer, 2016). However, this is one of the most important potential areas for improvement, with the McKinsey Global Institute (Barbosa et al., 2017) reporting a global productivity gap of $1.6 trillion that could be bridged by improving industry performance. The industry is seen as a slow innovator, especially when it comes to the adoption of digital technologies (Li et al., 2019). However, with the emergence of Building Information Modelling (BIM) there is evidence of change (Kassem & Succar, 2017; Li et al., 2019; Succar & Kassem, 2015), although the global adoption of BIM has been slow due to the risk and challenges perceived at the stage of adopting the technology, supporting processes and standards (Ghaffarianhoseini et al., 2017). Additionally, limitations in the knowledge and understanding of BIM (Winfield & Rock, 2018), which generate misconceptions amongst organisations and individuals about what technology can offer; often leads to abandonment and disappointment amongst those who come into contact with it (Ahmed & Kassem, 2018; Panuwatwanich & Peansupap, 2013).

Similarly, the Nigerian construction industry has been criticised for its lack of productivity and efficiency due to its fragmented nature (Abubakar *et al.*, 2014). This criticism is not far from the global construction industry situation (Farmer, 2016). The National Bureau of Statistics (2021) reported that the Nigerian construction industry's contribution to total real Gross Domestic Product (GDP) was 3.19% in the second quarter of 2021; this is lower than its contribution of 3.23% in the same quarter of the previous year, and the immediate past quarter where it contributed 4.12%. However, this figure remains low compared to other sectors' contributions to GDP, such as agriculture, crude oil production and trade. In terms of the growth of the Nigerian construction industry, "For the first half of 2021, growth was recorded at 2.40% compared to -15.99% in 2020. Quarter on quarter, the sector grew by -23.08% in real terms, higher than the -24.77% it recorded in the second quarter of 2020." (National Bureau of Statistics, 2021, pg 34). The negative values recorded in 2020 coincide with the period of the global pandemic. This indicates that, although the global pandemic negatively affected the growth rate of the Nigerian construction industry, the industry has recovered significantly (i.e. increases in the Nigerian construction industry growth rate). However, while the Nigerian construction industry is recovering significantly, the characteristics of the industry persist.

2.2.1 Characteristics of the Nigerian Construction Industry

In Nigeria, the increase in population has led to a rise in demand for housing and urban infrastructure (Obianyo et al., 2021; Oramah, 2016). Currently, the estimated population of Nigeria is about 206 million, making it the seventh most populous country in the world (World Bank, 2016). According to the United Nations, Nigeria's population is projected to increase to 263 million in 2030 and 401 million in 2050 when it will become the third most populous country in the world. In Africa, rapid urbanisation through rural to urban migration accounts for Africa's 40% urban population growth (World Bank, 2021, pg.36). In Nigeria, conflict and climate induced migration in recent years has increased and accelerated urbanisation in the country especially from the northeast (World Bank, 2021, pg.36). Therefore, Nigeria's unique nationality and transition to a more modern society has led to the remarkable development of the construction industry, which has had to respond to the needs of a large population. Accordingly, Obianyo et al. (2021) stated that, to cater for the growing population and urbanisation, there is a need to deliver sustainable housing solutions. Thus, a significant increase in construction demand has occurred.

2.2.1.1 Demand for Construction

The population growth and economic boom in Nigeria's last decade have led to high demand for construction activities. Just over a century ago, cities and urban areas in Nigeria did not exist. Mapogunge (1965) reported that about 20% of the total population of 32 million people lived in urban areas in 1952. However, this situation has considerably changed with the recent projection of 189 million urban dwellers between 2018 and 2050, which would nearly double its current urban population (United Nations, 2018). Hence, there is a need for infrastructure such as roads, dams, and buildings.

Traditionally, 90% of the construction industry's output was from the government, making the government the industry's largest client (Oxford Business Group, 2011). Currently, high economic and population growth, middle-class and upper-class growth, rural-urban migration, and a growing business environment support the industry's development and stimulate the increasing demand for housing, infrastructure improvement, and other services relating to construction. According to the World Bank (2016), the Nigerian population is projected to increase to about 401 million in the year 2050. Besides, the United Nations predicts that Nigeria will record the fastest population growth in the city over the next 40 years, leaving more than 200 million people living in cities across the country. This will put considerable pressure on housing and infrastructure and open up many opportunities for the construction sector. According to World Bank estimates, the housing deficit will be between 12-16 million units, while the Federal Government of Nigeria (FGN) projects will be between 15-23 million residential units (World Bank, 2013; FMLHUD, 2014; Oxford Business Group, 2015). Therefore, efforts to eliminate housing shortages have led to the high demand for construction, driving the industry's competition, and demand for materials and services.

2.2.1.2 High competition

As previously indicated, increased demand has made construction profitable in Nigeria. Nigeria's construction industry has always been considered a fiercely competitive market. Many foreign and domestic enterprises contend for a market share (Oxford Business Group, 2015). According to Adams (1997), in the 1990s, several emerging indigenous firms competed for technical projects on a scale never seen before. However, the recent influx of sizeable Chinese construction firms has shifted the balance away from the most prominent European firms that formerly dominated the Nigerian construction industry (Babatunde & Low, 2013). As a result, a market for construction materials has emerged. According to Omede & Saidu (2020), fluctuations in the price of construction materials are influenced by inflation in the price of oil in Nigeria. The impact of inflation in oil prices on the Nigerian construction industry is discussed in the next section.

2.2.1.3 Oil Prices and Inflation

The construction business in Nigeria is susceptible to fluctuations in crude oil prices for three main reasons. Firstly, oil is Nigeria's primary source of foreign currency, accounting for more than 95% of government revenue (National Bureau of Statistics, 2021). Secondly, the government remains the most critical client in the construction industry; as a result, construction activity spikes during periods of high return and plateaus during periods of poor price (Aregbeyen & Kolawole, 2015; Omitogun et al., 2018). Thirdly, the Nigerian economy has experienced several periods of high inflation resulting in significant cost overruns due to the economy's price fluctuations. Therefore, when the price of construction material spikes due to the inflation of oil prices, the initial project projection cost and procurement plan is negatively affected and this typically leads to construction project delays, disagreements, suspension, or abandonment (Balogun, 2016; Omede & Saidu, 2020). In this regard, oil price fluctuation needs to be considered when planning construction projects in Nigeria and therefore, this translates to additional funds to cater for unforeseen increases in building material prices during the construction project. Thus, contributions to the intensive capital demand for construction in Nigeria will be discussed in the next section.

2.2.1.4 Intensive Capital Demand

Intensive capital demand is a quality shared by the majority of the construction industry (ConsTrack360, 2021). Nonetheless, in the Nigerian context, various other factors that contribute to capital dependency are at work. Uncertainty and disproportionate reliance on imported building materials and international expertise, unreliable supply chains, and ineffective procurement management all contribute to the cost of construction (Omede & Saidu, 2020). The high initial expenses also contributes to the relatively high cost of plant and equipment maintenance.

2.2.1.5 Heavy reliance on unskilled labour

Due to Nigeria's enormous population, high unemployment rate, and high equipment prices, the construction business primarily relies on manual labour (Idoro, 2012). A sizable portion of this workforce is inexperienced and performs physically demanding tasks such as digging and demolition. Labour expenses are also relatively low, owing to the vast number of unemployed individuals eager to take on these duties. As a result, this affects the amount of time spent to complete the job and the quality of the work (Oyedele et al., 2015).

2.2.1.6 Professional Bodies in Nigeria

Construction activity remains unchecked due to weak regulations. The effect is an increased rate of building collapse, spontaneous urban growth, and defective materials. Milford (2012) describes two categories of institution: "development institutions, and builder and contractor association". Nigeria has been considering a development board for the construction industry. Nonetheless, in Nigeria, the responsibility for regulating the behaviour of professionals in the built environment rests with professional associations and their supervisory bodies unless binding regulations exist. These professional bodies set minimum standards for higher education in their disciplines, and provide members with practice licenses, which requires them to perform their duties under British Standards (BS) and the American Society for Testing and Materials (ASTM). The primary regulators of the built environment for architects, engineers, builders, planners, and surveyors are: the Architects Registration Council of Nigeria (ARCON), the Council for Regulation of Engineering in Nigeria (COREN), the Council of Registered Builders of Nigeria (CORBON), the Town Planners Registration Council (TOPREC) and the Quantity Surveyors Registration Board (QSRB), respectively. However, despite their annual conferences, a review of their publications and websites shows no tendency to focus on BIM adoption in the industry, higher education curricula, or practices (Olanrewaju et al., 2020). Nonetheless, considering the scope and context of this study, the professionals involved in this research are architects within the Nigerian construction industry. Thus, the subsequent section further explains the architects' role and position within the Nigerian construction industry.

To conclude, section 2.2.1 presents an overview of the Nigerian construction industry characteristics. The industry is fast growing with high demand for construction. Although it is lucrative, due to this high demand, it also brings about opportunities for material importation and investment by foreign companies. The Nigerian construction industry is heavily reliant on unskilled labourers. However, due to the high population density, the cost of labour is reasonably affordable. Furthermore, Nigeria is an oil-dependent nation; therefore, the construction prices fluctuate based on the oil prices. Additionally, professional bodies regulate and check construction activities, including ARCON (the Architects Registration Council of Nigeria). The focus of this study is the architectural practice that ARCON regulates. Despite regulation, challenges still plague the industry, thus, the following section presents these challenges.

2.2.2 Challenges of the Nigerian Construction Industry

According to the Work Bank report (2018), Nigeria is the 27th largest economy in the world and the largest in Africa ahead of South Africa and Egypt. There is a growing demand in all areas of the industry, from basic infrastructure to specially designed real estate. This has already brought many players to the market. The number of contracts offered will increase dramatically over the next ten years. However, several challenges need to be addressed for the country to reach its full potential. While the operating environment for construction companies has improved over the past five decades, concerns remain over the Nigerian construction industry's many organisational, administrative, structural, and financial aspects. The main challenges are: access to funds, substandard construction data, poor or limited managerial skill, and lack of transparency.

The funding of construction projects is a long-standing feature of construction in developing countries such as Nigeria. Akintoye & Renukappa (2012) identified several funding problems in developing countries, including globalisation and insufficient banking services. Although the banking sector in Nigeria has grown significantly over the past decade, construction SMEs in the Nigerian market are still trying to increase their capital. Therefore, this provides a strategic advantage to foreign companies to quickly generate more wealth offshore (Coffey International, 2014).

The accuracy of Nigerian data and statistics is highly questionable, so data estimation also considers a wide range of variables and figures. The National Bureau of Statistics (2021) has recently improved its data collection capacity. Nonetheless, there are still questions about reliable statistics involving, for example rural-urban migration, population and employment figures. Combined with a broad informal sector, a large proportion of the rural population makes it challenging to obtain accurate statistical data. In addition to financial challenges and unreliable data, the Nigerian construction sector lacks skilled labour (Dania et al., 2014). The poor management capabilities of the Nigerian construction industry were illustrated by time and cost overruns, low productivity and the domination of international construction firms in large commercial and public construction markets (Fagbenle et al., 2018; Saidu & Shakantu, 2017a). Hence, Agbonlahor (2016) suggests that practitioners in the built environment in Nigeria concentrate on entrepreneurship and management skills.

Transparency problems have varying degrees of effect on both developed and developing countries (Kasimu, 2016). Allegations of lack of transparency and corrupt practices have troubled the Nigerian construction industry for a while (Olusegun et al., 2011; Ameh & Odosami, 2010). Such accusations are difficult to prove and even more difficult to prosecute because most construction firms are not willing to discuss the issue. Nevertheless, studies related to the Nigerian construction industry, including Kasimu (2016) and Obianyo et al. (2021), also discuss corruption. Corruption is said to have a significant impact on construction quality and the loss of revenue to investors.

2.2.2.1 Challenges Due to Fragmentation of the Industry

Smith (2002) argues that the characteristics of a project should not be unclearly defined and misunderstood because this can lead to slower delivery and higher costs. Furthermore, a misinterpreted project might lead to a flawed project process which results in a counterproductive outcome. Therefore, the planning and implementation of the project process becomes more crucial as the complexity of a project increases. The challenges arising from the fragmentation of design and construction teams can snowball, causing a slew of issues in construction projects. Thus, the challenges encountered within the Nigerian construction industry due to the fragmentation of design and construction process are as follows:

2.2.2.1.1 Delays in Project Delivery

When a project's completion date exceeds the anticipated timeline, it is considered a delayed project. Aibinu & Jagboro (2002) identified the delays in construction projects delivery among the Nigerian construction industry challenges. They also explained that a delay happens when the contractor and project owner do not complete the project at the agreed time, which leads to an unsuccessful project.

Delays indicate a new budget when a project has to be extended beyond the scheduled time or poor delivery quality due to the acceleration process (Aibinu & Jagboro, 2002). Additionally, Egwim et al. (2021) affirmed that the Nigerian construction industry suffered severe delays in construction projects. Abubakar *et al.* (2014) highlighted a need for the Nigerian construction industry to improve its infrastructure value, project quality, time and cost delivery. The construction industry has been developed previously through using new contractual/procurement arrangements such as partnering, concurrent engineering (Khalfan et al., 2001), integrated project delivery (Kim & Dossick, 2011), and technological innovations in design and construction processes such as 3D CAD and modelling (Aiyetan, 2018; Underwood & Isikdag, 2011). One of the essential innovation processes described as a promising tool to achieve the improvements needed in the construction industry is BIM (Abubakar et al., 2014).

Furthermore, in a paper targeted at identifying the causes of project delays Adebakin & Ipaye (2016) established that numerous project deliveries and procurement techniques used in the industry harmed the timely delivery of projects. Adekunle & Ajibola (2015) highlighted the fragmented approach that results in disagreements throughout the procurement process, causing challenges during the decision-making process and a cascade of delays. Aibinu & Odeyinka (2006) developed an index of important factors contributing to delays in the Nigerian construction industry, with financial issues ranking number one among other identified factors, such as design management and collaborative challenges with specialised trades. Nonetheless, several experts highlighted that the fundamental cause of project delays is inadequate integration and a lack of collaborative practise among stakeholders throughout the construction process (Adekunle & Ajibola, 2015; Kog, 2017; Sunjka & Jacob, 2013). However, the benefits of BIM come from more effective collaboration between stakeholders based on a shared project vision (Wang et al., 2020). Thus, according to Wang et al. (2020), the challenge rests on developing a collaborative approach to improving communication between different stakeholders, which further promotes the need to introduce BIM in construction projects.

2.2.2.1.2 Cost Overrun

As the name implies, cost overrun denotes a basic overrun of costs, which means that they exceed planned levels upon completion or during the building of projects. Cost overruns continue to be a global issue, with nearly 90% of construction projects internationally reported to have exceeded budgets (Saidu & Shakantu, 2016). Over the last two decades, the Nigerian construction industry has struggled with cost overruns. Mansfield et al. (1994) evaluated building project management approaches in Nigeria and discovered a significant difference between estimated construction costs. It is worth noting that most of these project management practices determined to be poor and directly contributed to cost overruns have remained unchanged. A recent cost overrun study by Saidu & Shakantu (2017) showed that the buildings reviewed had an average completion rate of 52.4%, and exceeded the initial cost by 44.46%.

Additionally, cost overruns continue to be a significant issue in the Nigerian construction industry as a result of a variety of factors, including poor design during the design phase of traditional procurement, insufficient expertise among the construction team, and inadequate funding (Malumfashi, 2012; Ogunsemi, 2006 Saidu & Shakantu, 2016). Thus, these further emphasise the importance of an integrated approach in the Nigerian construction industry, as the 1990s process is still widely used today. According to Moledina et al. (2017), cost overruns lead to disputes and further delays. Moledina et al. (2017) compared traditional cost estimation with advanced cost estimation (i.e. BIM approach) in Malaysia. The outcome revealed the superiority of the BIM approach in terms of the accuracy over the traditional Bill of Quantity (BOQ), especially in large projects. Similarly, Btoush & Harun (2017) affirmed that BIM plays an essential role in minimising construction project delays, leading to cost and time overruns within the Jordanian construction industry. Thus, several countries have acknowledged the potential of BIM to mitigate cost overruns.

2.2.2.1.3 Occurrence of Rework

Rework is a widespread issue that has a detrimental impact on construction project performance and has become one of the most prevalent concerns in academia and industry (Bon-Gang et al., 2019). The Nigerian construction industry has seen a significant amount of projects overrun in cost and riddled with delays due to rework. In a thorough investigation into rework in Nigeria, Oyewobi & Ogunsemi (2010) pinpointed that the primary causation was conflicting information between the construction and design team due to inexperienced workers and inadequate construction planning. Rework in the construction industry has a severe ripple effect on the outcome of the construction project. Oke & Ugoje (2013) reported that substructures with complicated designs accounted for the highest amount of rework in most projects examined in their investigation. Eze & Idiake (2018) suggested that, to eradicate rework in Nigeria, a general agreement is needed to bring together the client, contractor, and consultant in a collaborative environment from the project's inception. Abiodun & Nwaogu (2021) also pointed out that stakeholders must understand that collaboration presents an effective solution to rework issues. Therefore, management must pay adequate attention to several factors that can lead to adversarial issues resulting from rework and mitigation through teamwork. According to Manzoor et al. (2021), Malaysia like most developing countries, struggles to achieve their construction project goals due to budget and schedule overruns, which results in project delays and inefficiency. However, the use of an advanced digital assisted approach, such as BIM process, reduces errors, rework and waste. This is because using BIM in construction projects facilitates multidisciplinary collaboration between different project teams, and increases productivity during construction project activities (Oraee et al., 2021).

2.2.2.1.4 Poor Building Performance

Chan (1995) believed that project performance is significantly enhanced when the design and construction teams collaborate from the project's inception to completion. However, East (2014) highlighted that several years are required to review and transcribe documents to ensure a built asset performs as designed. Therefore, the maintenance phase of the project is crucial to confirm that the designs perform adequately. In Nigeria, several reports have emerged of buildings/facilities functioning inappropriately or not as designed (Aibinu & Odeyinka, 2006; Idrus et al., 2010; Ogwueleka, 2011). Additionally, Idrus et al. (2010) highlighted a massive gap in understanding what the client and contractor referred to as a "high quality" facility, while evaluating the performance of contractors in Nigeria. This gap contributed to the low satisfaction rate of clients in Nigeria. Furthermore, Ogwueleka (2011) primarily linked poor building quality and performance to design management amongst other contributing factors, such as project planning and control, participants' commitment, communication between stakeholders, and a lack of innovative concepts.

2.2.2.1.5 Collapses and Fatalities

In Nigeria, building collapse (resulting from several factors) is responsible for the loss of lives and investment, which presents enormous challenges for the government and professional bodies. 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 54 buildings in the nation from 2012 to 2016 (Nnodim, 2017). The report shows that design management played a crucial role in the incidents. Before this, Ayodeji (2011) noted a series of collapses in the country and examined the causes and effects. This examination and many other researchers revealed that building materials were substandard, and workers' skills were inadequate. However, the most relevant revelation was defects in design and disconnection between the designer and contractor (Ayodeji, 2011; Fagbenle & Oluwunmi, 2010; Oloke et al., 2017). Thus, due to these issues, Oloke et al. (2017) developed a framework for integrity tests at different stages of the building life cycle. This framework required the collaboration of stakeholders and requested that the building had facility managers. Thus, effective collaboration between stakeholders, such as designers and contractors, and/or a systemic approach for assessing the integrity and safety of a building can reduce or eliminate building collapse.

2.2.2.1.6 Poor Quality of Project Delivery

The quality of construction projects is a worldwide issue and has received the attention of various studies (Ali, 2014; Jong et al., 2019; Ma et al., 2018). In the Nigerian construction industry, clients commonly deem projects unsatisfactory, unfit for purpose, and below standard after completing a construction project. Tanko et al. (2017) demonstrated that among the factors that cause poor quality in project delivery are design changes and low collaboration between professionals. Similarly, Ogundipe et al. (2018) highlighted that poor project delivery quality was due to inappropriate procurement strategies, which hinder construction professionals from integrating or collaborating. However, Ikediashi & Ogwueleka (2016) reaffirmed this issue and recommended that the implementation of Information and Communication Technology (ICT) improves the quality of work immensely by providing construction professionals with a platform to integrate, thereby improving collaborative practices.

2.2.2.1.7 Abandoned Buildings

The nation has also seen various forms of difficulties in completing construction projects over the past few years. According to Olusegun et al. (2011), about 4,000 government construction projects in Nigeria have been abandoned or delayed for several years. These delayed projects will take at least 30 years to complete at the current rate. Additionally, Doraisamy et al. (2015) reported that abandoned projects owned by private businesses/individuals and various tiers of Nigerian government are worth around 12 trillion Naira (£240 million). This series of abandoned buildings across the nation has contributed to the country's severe infrastructure deficit. Consequently, various bodies, such as the Nigerian Institute of Quantity Surveyors (NIQS), Nigeria Institute of Building (NIB) and Nigerian Institute of Architects (NIA), have conducted awareness workshops or debated possible solutions to address the plague of abandoned projects across the country (Alao & Jagboro, 2017).

Additionally, the investigation by Isibor et al. (2016) revealed that the primary factors that cause the abandonment of building projects are a lack of funding or engagement in several projects meaning the adequate availability of funds. However, improper design, lack of construction, and estimate plans were significant contributing factors in most buildings. Similarly, Olusegun et al. (2011) revealed that abandoned buildings in the nation resulted from poor collaboration between the design and construction teams and, most importantly, the client. Therefore, it is evident that poor collaboration between stakeholders leads to faulty designs due to inaccurate estimates. This, leads the contractor to have buildability issues that produce poor outcomes bringing the overall project to a halt.

In conclusion, section 2.2.2 provided insights into the Nigerian construction industry's challenges with a particular focus on those influenced by the fragmented nature of the industry. A lack of effective collaboration between stakeholders, inaccurate project estimations, and the occurrence of rework due to inadequate construction planning are factors that can lead to construction project delay. However, the delay of a project can incur additional charges, which might lead to cost overruns and ultimately the abandonment of the project. Therefore, the need to introduce a new approach to construction project design and delivery is apparent in order to mitigate these challenges. Nonetheless, several studies have documented that BIM significantly mitigates challenges similar to the Nigerian construction industry. For example, Bensalah et al. (2019) affirmed that a BIM process is able to overcome delays in procedure slowing the development of the construction industry in many countries, especially in Morocco, because a BIM process improves the design integration process, internal project team communication, and collision detection to eliminate the risk of rehabilitation. Therefore, it is important to understand the concept of BIM and its role in curbing the challenges within the Nigerian construction industry. Thus, the following section presents the concept of BIM and its current status within the construction industry.

2.3 Building Information Modelling

The concept of Building Information Modelling (BIM) could be traced back to Eastman et al.'s description of BIM as a "Building Description System" (Eastman, 1974). In contrast, Robert Aish used the phrase "Building Modelling" in 1986, including 3D modelling and real-time building simulation (Aish, 1986). However, although the term 'Building Information Model' was first used in 1992 (Nederveen, 1992), Building Information Modelling was coined later in 1999 (Tolman, 1999). Accordingly, Sacks et al. (2018) mentioned that the origin of BIM can be traced back to the 1970s and 1980s when object based parametric modelling was developed for manufacturing.

According to Matarneh, Danso-Amoako, Al-Bizri, Gaterell, & Matarneh (2019), technological advancements facilitated the shift from a two-dimensional paper-based design to a three-dimensional collaborative digital model. Therefore, a single model containing all the necessary information, files and documents related to a project which is developed through the effective collaboration of the stakeholders involved in the project is referred to as a BIM model (see Figure 2.1). In this regard, BIM models have parametric advantages over CAD because discrepancies in the documentation, designs or project plans can be coordinated and identified early.

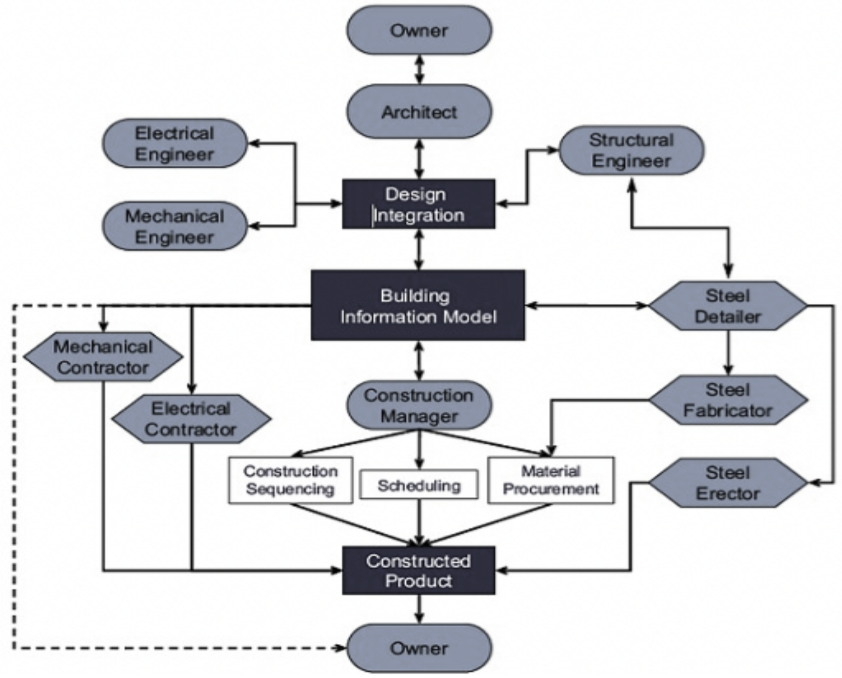


Figure 2.1: The concept of BIM
(Bruce and Burt, 2009)

Figure 2.1 shows the holistic concept of BIM where the owner (or client) interacts with the architect to translate the design needs and requirements. The architect collaborates with the mechanical, electrical, and structural engineers to produce an integrated design called the 'BIM model'. Therefore, BIM is the process of developing the BIM model. Additionally, the BIM model includes information on all the components of a project. This information might be related to the construction manager (i.e. scheduling, material procurement or construction sequence) and/or contractors (i.e. mechanical, electrical or structural). BIM helps a designer, such as an architect, engineer or construction professional, create a design more effectively than other CAD tools. Every component on a BIM model is a BIM object. For example, BIM objects, such as windows or doors, would have embedded product properties such as thermal performance, physical characteristics, graphical information about the product's appearance, and functional data. The process of BIM enables the creation and management of 3D virtual models, which users (clients and professionals) can explore. Thus, the BIM concept provides an opportunity to make quick collaborative decisions, and improve the processes, culture and value outcomes within the construction industry, as discussed in the subsequent section.

2.3.1 The Definition BIM

Despite the popularity of BIM, there is no consensus on its definition (Doan et al., 2020). However, a review of the various definitions of BIM shows a convergence of the concept of BIM (see Appendix 2). For example, BuildingSMART (2016, p1) defined BIM as *"a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward"*. While, according to Autodesk (2021), BIM is defined as the *"… holistic process of creating and managing information for a built asset. Based on an intelligent model and enabled by a cloud platform, BIM integrates structured, multi-disciplinary data to produce a digital representation of an asset across its lifecycle, from planning and design to construction and operations"*. Similarly, Hamil (2021) defined BIM as *"a process for creating and managing information on a construction project, throughout the project's life cycle. As part of this process, a coordinated digital description of every aspect of the built asset is developed, using a set of appropriate technology. It is likely that this digital description includes a combination of information-rich 3D models and associated structured data such as product, execution and handover information"*.

Although BIM has been interpreted differently by individuals over the years (Eastman 2011), the convergent key concept of BIM is that it provides the ability to efficiently and collaboratively integrate the creation and management process of all relevant data/information throughout the whole life of the built asset (i.e. from inception to demolition – site activities, design planning, construction process, post occupancy evaluation, management decisions and maintenance). Recently, as a response to the Hackitt report following the Grenfell Tower fire, a recommendation was made for BIM to achieve a "golden thread" of information (NBS, 2020). According to BRAC (2021), *"the golden thread is both the information that allows you to understand a building and the steps needed to keep both the building and people safe, now and in the future"*. This reaffirms the widespread acceptance of BIM as a well-established approach to sharing the data of a facility (such as buildings and infrastructure) across the design, construction and operation phases.

Furthermore, BIM is considered a value driven approach to project delivery which offers an opportunity for a paradigm shift in collaborative construction work practices (Khosrowshahi, 2017). However, in the Nigerian context, this paradigm shift in construction work practices often distorts the business environment within the SMAFs (Kori, 2015). Additionally, the distortion of the business environment is often associated with a lack of clear understanding of BIM's business value and its adoption process within Nigerian SMAFs (Babatunde 2020; Kori, 2017). This is not dissimilar to the construction industry in France where companies shy away from BIM adoption due to an insufficient understanding of the process (Martin et al., 2019). Therefore, the need for a clear guide to understand BIM's business value and adoption process would contribute towards the successful transition from traditional practices to BIM practices within Nigerian SMAFs. Nonetheless, to effectively support firms and ensure a successful digital transition to BIM practices, there is a need to measure a firm's maturity level in the deployment of BIM. Thus, the next section discusses the various BIM maturity levels utilised to assess a firm's level of BIM deployment.

2.3.2 Maturity Levels of BIM

The BIM maturity levels emerged as a result of a lack of absolute clarity regarding BIM's implementation stages and measuring scale. Therefore, the maturity levels can be used to denote the various stages of BIM implementation (Khosrowshahi & Arayici, 2012). According to Yilmaz et al. (2019), BIM maturity and capability models are developed to assess and measure the level of BIM implementation of BIM users. The National Institute of Building Science (NIBS, 2007) developed and introduced the National BIM Standard Capability Maturity Model (NBIMS-CMM). The NBIMS-CMM includes 11 key BIM metrics, including business processes, delivery methodology, data richness, and accuracy of information. However, critics questioned the usefulness and usability of NBIMS-CMM due to structural constraints because it focused exclusively on information management and failed to express various aspects of BIM (Succar, 2010). This profound and intense criticism led to new models that have attempted to develop NBIM-CMM. Maturity models, such as the BIM maturity matrix (Succar, 2010), BIM maturity level (Barlish & Sullivan, 2012), Virtual Design and Construction (VDC) Scorecard (Kam, 2015) and the BIM maturity measure (BIMMM) (Ammar et al., 2017) are intended to enhance the prevalent maturity models. However, to assess the level of BIM adoption amongst Nigerian

SMAFs, it is essential to consider the different maturity and capability models related to the BIM implementation process.

However, Succar (2009) describes three fixed BIM maturity levels, which start immediately after the pre-BIM level (i.e. the status prior to BIM adoption) and end with a post-BIM level that accommodates any unforeseen future technological advancement. As shown in Figure 2.2, the three BIM maturity levels include:

a. Modelling (Object-based);
b. Collaboration (Model-based); and
c. Integration (Network-based).

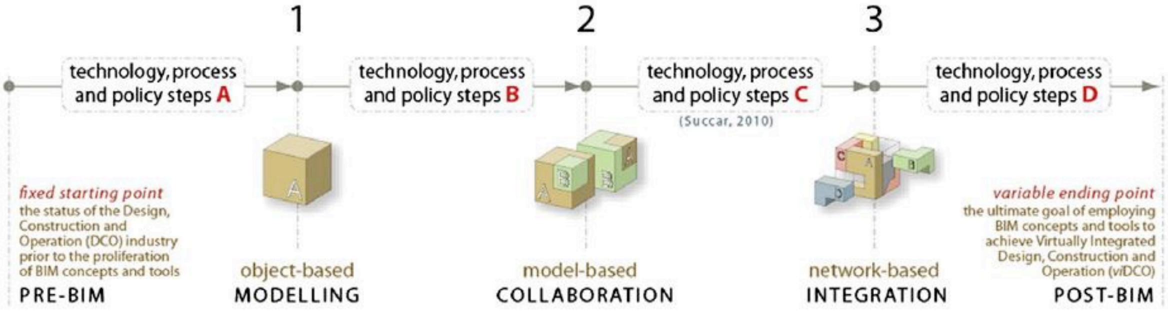


Figure 2.2: BIM Maturity Levels
(Succar, 2009)

a. BIM level 1 – Modelling (Object-based);

From Figure 2.2, collaborative practices in level 1 are similar to the situation in pre-BIM, and there is no meaningful model-based exchange between different disciplines. Data exchange between the project participants is one-sided, and the communication remains asynchronous and incoherent. As there are minor changes in the process at level 1, the contractual relationships before BIM, risk diversification and organisational behaviour will continue. However, the semantic nature of the object-based models and their "appetite" for early and detailed decisions on design and design challenges foster the rapid tracking of project lifecycle phases - when the project is still running incrementally. At the same time, activities are designed and created to overlap in a time-saving manner. Additionally, as highlighted in Figure 2.3, to reflect the implementation requirements and performance targets, BIM maturity Level 1 could be further customised into five distinct levels including ad-hoc, defined, managed, integrate, and optimised *(Succar et al., 2012)*.

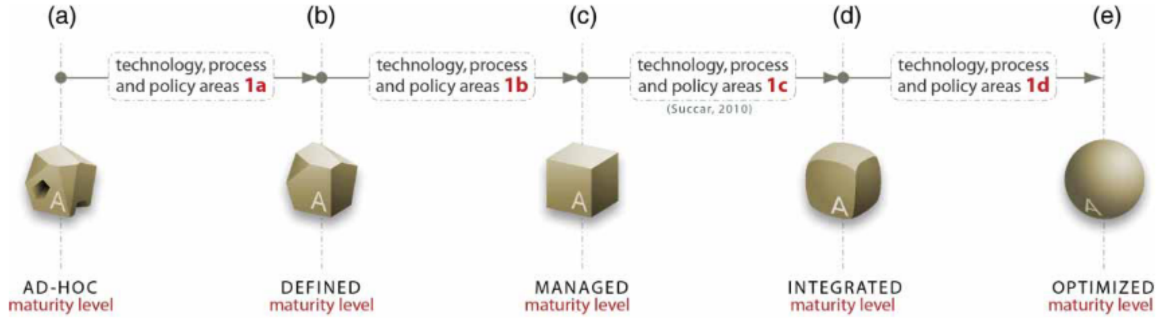
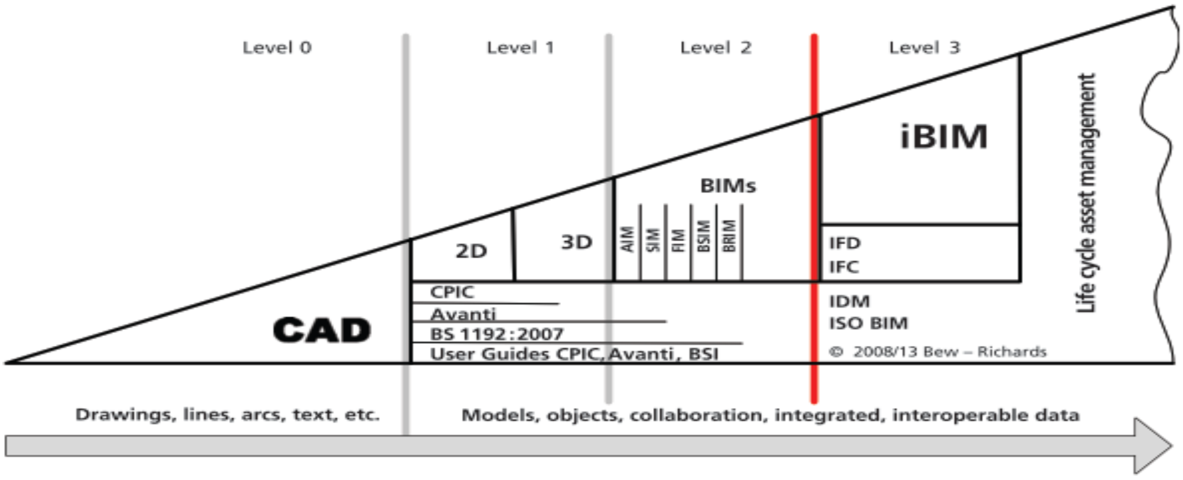


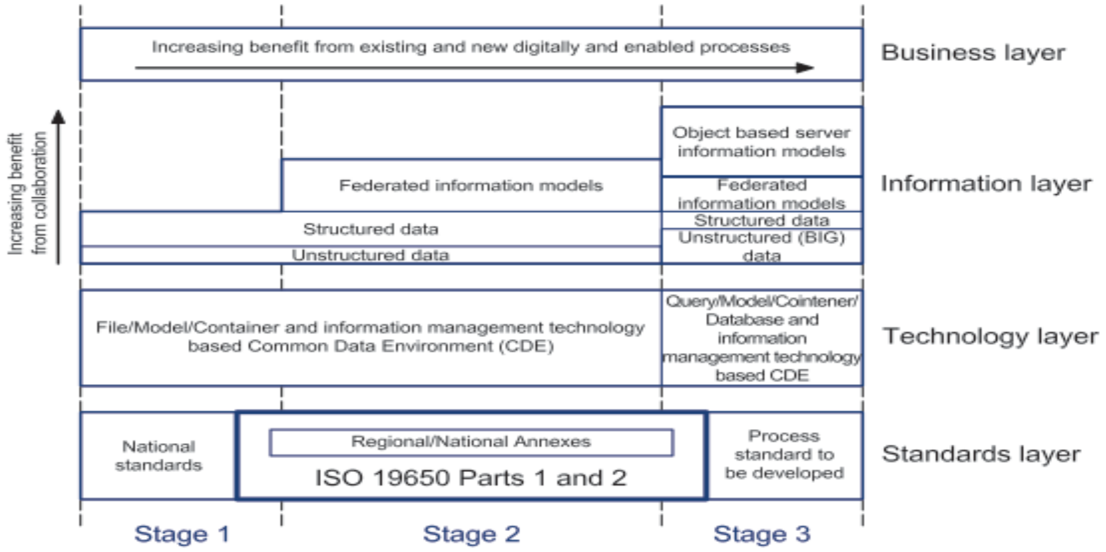
Figure 2.3: BIM maturity diagram
(Succar et al., 2012)

b. BIM level 2 – Collaboration (Model-based);

At this level, communication between BIM representatives remains asynchronous; the dividing lines between roles, disciplines, and lifecycle stages from the pre-BIM level begin to fade. Some contractual changes become necessary as models are exchanged and gradually replace the document-based workflow. Level 2 also changes the modelling accuracy at each stage of the lifecycle, as detailed building models evolve to (partially or completely) replace the low-detail design models. However, as shown in Figure 2.4, BIM Level 2 based on the BIM wedge as shown in PAS 1192-2:2013, is now superseded by the BS EN ISO 19650 series. Although the principles of ISO 19650 remain the same as the BIM Level 2 documents, the new structure is designed to make the understanding and implementation process easier (BSI, 2019).



a) UK maturity model from PAS 1192-2:2013, Figure 1



b) ISO diagram from BS EN ISO 19650-1:2019, Figure 1

Figure 2.4: BIM maturity diagram and ISO diagram
(BSI, 2019)

c. BIM level 3 – Integration (Network-based)

At this stage, rich integrated models are created, shared, and managed collaboratively throughout the life cycle stages of the project. This integration can be achieved through server technologies (proprietary or non-proprietary formats), integrated/distributed databases, cloud computing or SaaS (software as a service). Stage 3 BIM models have become nD interdisciplinary models that allow for sophisticated analysis from the early virtual design and construction stages. At this stage, the model's performance transcends the characteristics of semantic objects and includes business intelligence, Lean design principles, environmentally friendly policies, and lifecycle estimations. Collaborative work is now rotating "iteratively" around a standardised data model that could be shared. From a process perspective, the simultaneous exchange of model-based and document-based data means that the project life cycle phases overlap considerably and form a progressive process.

In conclusion, the three levels of BIM maturity are essential to evaluate and assess the BIM implementation stages, namely level 1 (modelling), level 2 (collaboration), and level 3 (integration). This notion has been reaffirmed by various studies particularly in the context of Nigerian SMAFs (S. Babatunde, Udeaja, et al., 2020; Hamma-adama, Kouider, et al., 2018; Kori & Kiviniemi, 2015; Kori & Makarfi, 2018; Ugochukwu et al., 2015). Furthermore, the level of BIM maturity is strongly associated with the BIM dimensions (Bew & Richards, 2008; Martin et al., 2019). For example, Smits et al. (2017) argued that the only reliable indicator to time (4D), cost (5D) and performance (6D) is the level of BIM maturity. Additionally, LetsBuild (2019) reiterated the association of BIM maturity level with BIM dimensions by describing BIM level 1 as a transition stage from CAD to 2D and 3D information, BIM level 2 as a stage that focuses on information sharing with additional dimensions 4D (time management) & 5D (budget calculations), and BIM level 3 as a full integration (iBIM) stage that introduces 6D (management of asset lifecycle). Considering the association of the BIM dimensions with the BIM maturity levels, it is deemed necessary to further discuss (in the subsequent section) what the dimensions represent.

2.3.3 Dimensions of BIM

As BIM evolved over the years (i.e. moving from 2D CAD packages to 3D modelling systems), the need to differentiate between 2D or 3D geometry became prominent (Hamil, 2021). However, as BIM continues to evolve, dimensions were needed to differentiate the ways in which specific data are linked to the information model and used to manage and deploy different aspects of construction projects, as shown in Figure 2.5. For example, levelling up these dimensions gives BIM users a better understanding of their construction model *"the extended use of 3D intelligent design (models) has led to references to terms such as 4D (adding time to model) and 5D (adding quantities and cost of material) and on and on"* (AGC, 2006, pg.3). According to Ahmed, Emam & Farrell (2014), the generally accepted BIM dimensions are 3D (spatial dimension), 4D (time dimension), and 5D (cost dimensions). However, beyond the 5th BIM dimension (i.e. 5D cost dimension), the extended dimensions are understood and named differently by different researchers and organisations. Therefore, it is important to precisely state the specific information and format required for modelling and inclusion in the BIM project design rather than just use terminology such as 6D (sustainable dimension), 7D (maintenance dimension), 8D (safety dimension) or nD (Nth generic dimension). For example, an appointing party could more precisely state that sustainability (such as the embodied carbon for all structural material measured in CO_2e/kg) is required in the BIM model rather than just say the requirement is a 6D embedded BIM model.

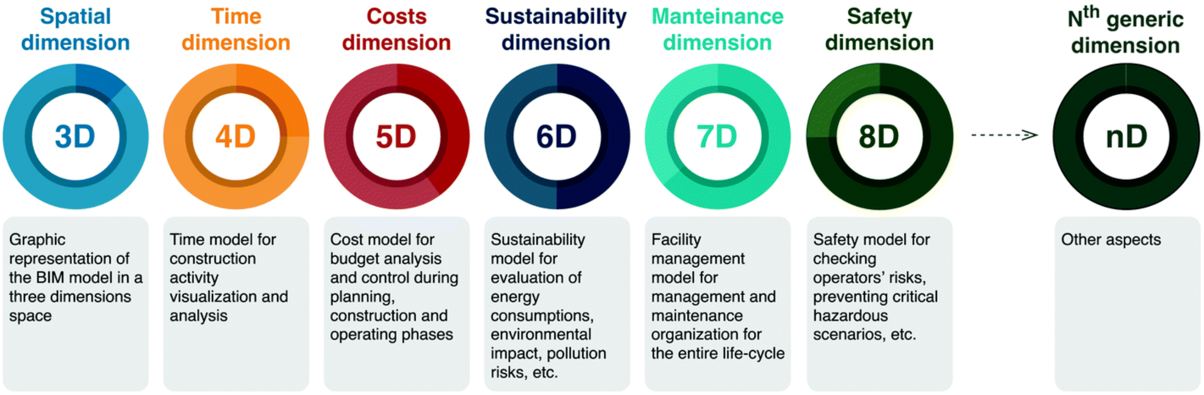


Figure 2.5: BIM dimensions and descriptions
(Bosurgi et al., 2020)

Figure 2.5 indicates that BIM dimensions can be utilised for pre-defined specific purposes commonly known as use-cases. According to the project stage requirement and project complexity, specific parameters are added to the existing information contained within the BIM model. The addition of pre-defined used cases can be described as BIM dimensions. These dimensions enhance the data associated with a model to share a greater understanding of a construction project. Furthermore, each BIM dimension (3D, 4D, 5D, 6D, 7D, 8D … nD) serves a specific purpose in determining the estimated cost, completion timeline, and future sustainability. Therefore, implementing BIM across these dimensions contributes to the benefits and value that BIM offers when planning and managing construction projects (Kapogiannis et al., 2015). Thus, the subsequent section discusses the benefits of BIM with specific reference to the dimensions and challenges of the Nigerian construction industry.

2.4 Benefits of BIM to Drive Adoption

The need for effective information management with documented accountability and responsibility for activities and task across the whole life of an asset has increased in recent year (UKBIM Framework, 2021). According to the UKBIM Framework (2021), the effective management of information can help to achieve better project outcomes through: improved coordination and communication, better quality information production, timely information delivery, mitigated rework, unnecessary waste and cost, effectively informed decision making, and more accurate audit trails/record keeping. Thus, considering ISO 19650 – 2, BIM has the potential to facilitate the effective management of the information needed to deliver better project outcomes. For example, providing the right level of information to the right individuals and at the right time would enable decision makers to make informed decisions and therefore, help clients get what they request (i.e. hospitals that deliver better healthcare or schools that deliver better education).

Accordingly, a considerable amount of literature has discussed the benefits and drivers of BIM adoption within SME’s (Ahn et al., 2016; Fakhimi et al., 2017; Ghaffarianhoseini et al., 2017; Hong et al., 2016). However, in the context of the Nigerian construction industry, the drivers of BIM adoption to Nigerian construction industry are aligned to the benefits of implementing BIM within the construction industry (S. Babatunde et al., 2018; S. Babatunde, Ekundayo, et al., 2020; Olanrewaju, Babarinde, et al., 2021; Saka et al., 2020). For example, Olanrewaju et al. (2021), investigated and highlighted 15 drivers for implementing BIM within the Nigerian construction industry, which are directly associated to the benefits of BIM adoption such as construction process visualisation, potential economic benefits, controlled whole-life cost and environmental data, increased efficiency and coordination, improved productivity and collaborative decision making. Similarly, Saka et al. (2020) reviewed the drivers for sustainable BIM adoption and implementation in Nigerian SME’s, and highlighted 19 drivers including cultural change in project delivery towards improved project information management, improved project collaboration and overall increases in the asset’s whole lifecycle value. Accordingly, the above drivers are also considered to be benefits of adopting BIM, as discussed further in this section. Thus, following the discussion of the BIM dimensions in the previous section (see section 2.3.3), the benefits and drivers of its adoption identified from the literature review can be summarised under the various BIM dimensions, as follows.

The 3D BIM dimension, which provides a graphical representation of the BIM model in a 3D space, offers benefits such as enhanced visualisation and simulation of the built asset (i.e. building, structure or facility) during the design, construction, and operational stages. This is useful to all stakeholders involved in the project such as clients, manufacturers, and contractors (Badamasi et al., 2021). In a project environment, the 3D BIM dimension facilitates collaboration and communication between stakeholders irrespective of their background when planning or making decisions at the design, construction, and operational stages (Costin et al., 2018). The ability to visualise an asset in a 3D environment reduces rework due to the transparency and understanding of design expectations from an early design stage (Costin et al., 2018). Rework has been identified as among the challenges within the Nigerian construction industry, which results in cost overruns, time overruns and ultimately project delays. Similarly, clients and sponsors of the project can visualise how the proposed finished product might look in a virtual environment using VR/AR technology, and any concerns can be addressed early in the design stage to save time and mitigate rework (Badamasi et al., 2021). Visualisation in 3D also helps to avoid design defects and the problems associated with prefabricated objects but also proves helpful when planning complex composite objects and arranging reinforcements (Li et al., 2019; Liu et al., 2018; Zheng et al., 2019). Therefore, the ability to model in a 3D BIM dimension can be beneficial in identifying clashes among structural elements right from the design stage. This assists in streamlining the design processes, saving cost and analysing the constructability of an asset.

The 4D BIM dimension is an additional time model visualisation and simulation for the construction activities. Therefore, using 4D phase scenarios by following the sequence of construction activities, logistical issues such as truck moving and swinging lever areas can be highlighted and mitigated before the project starts, saving time and taking adequate safety measures (Martínez-Aires et al., 2018). The benefit of 4D over 3D is that when detecting clashes in a project, without the time dimension, it is difficult to understand the construction sequence. For example, when demolishing and building a new wall in the same space, it can be identified as a clash in a 3D environment, but when simulating the scenario in a 4D environment, the sequence would be clearly understood. Thus, adequately utilising the 4D capability of BIM improves the project coordination, particularly during the construction phase, and mitigates the challenges faced by the Nigerian construction industry, such as project delays due to improper coordination during the design and construction stages (S. Babatunde et al., 2018). Additionally, 4D BIM can be used to digitally rehearse the construction sequence with site workers, such as builders, contractors, and consultants, to ensure that everyone understands the construction and plans the procurement routes before the construction process commences (Rowlinson, 2017). This saves time, reduces rework and provides an opportunity for any comments or suggestions to be addressed early.

The parametric nature of BIM allows objects to be linked based on their associated parameters (Sacks, Eastman, et al., 2018). Therefore, 5D dimension BIM model, which associates the cost model for budget analysis and control during the planning, construction and operating phase to the BIM model, would enable the automatic generation of accurate estimates based on the bill of quantities (Ghaffarianhoseini et al., 2017). Thus, any changes made by the designer will automatically be harmonised with the cost and schedule without much rework, thereby maintaining accuracy in the quantities (Ajayi & Oyedele, 2018). For example, if the client needs the financial impact of change requests and other changes, it is easier to create this quickly by integrating 5D data to the BIM model from the design stage (Röck et al., 2018). However, the level of accuracy in the cost estimation is highly dependent on the designer (Tagg, 2017). In this regard, a 5D BIM approach improves the decision-making process particularly for quantity surveyors and decision makers when analysing financial impact of the project or built assets.

Globally, the construction industry is moving towards designing, constructing and operating assets (i.e. facilities, buildings or infrastructures) with greater sustainability in order to reduce the overall energy consumption and carbon emission (Edwards et al., 2019). For example, in the UK, to meet the national CO2 emission target, approximately 28 million buildings will require refurbishment by 2050 (Edwards & Townsend, 2010). Therefore, during the early design process, BREEM and LEED are now established to measure the environmental impact assessment of energy in order to produce buildings that are more energy efficient and to reduce carbon emissions (Meex et al., 2018). In this regard, BIM is recognised as a potential powerful driver for promoting and leading the construction industry towards achieving its sustainability goals (Reizgevičius et al., 2018). Through sustainability information is included in the 6D BIM model, this enables the evaluation of energy consumptions and an environmental impact assessment (Charef et al., 2018). Furthermore, to affirm the importance of 6D BIM in the Nigerian construction industry, efforts to develop an assessment framework has been developed to evaluate the sustainability performance of buildings within the context of the Nigerian construction industry (Olawumi & Chan, 2020). However, according to Olawumi & Chan (2020), the study was an attempt to facilitate BIM adoption, thus, further reinforcing the need for BIM adoption within the Nigerian construction industry.

BIM value comes from the entire lifecycle information/data that are embedded within the model, to not just utilised during the capital delivery (i.e. design and construction), but also after handover and commissioning (Hardin & McCool, 2015; Machete et al., 2021). However, according to Mohammad et al. (2018), a 7D BIM model contains an entire asset's lifecycle data, which is required for operating, managing and maintaining the built asset. Therefore, this is particularly useful when developing the as-built BIM models containing information detailing the entire life data from inception to demolition, which can be utilised to create soft landings for the owner to detail out the transition strategy from construction to occupation, produce bespoke data on installed systems which is beneficial to manufacturer, and guide the facilities managers to navigate and maintain the assets (Hamil, 2021). The additional benefits of BIM with respect to the 7th dimension are that it could be utilised to digitally preserve the heritage and experience of assets that are at the end of their lifespan. This concept is referred to as heritage BIM (HBIM) according to Castellano-Román &

Pinto-Puerto (2019). Thus, in the context of the Nigerian construction industry, researchers such as Onungwa et al. (2017) affirm the potential of BIM as a management tool.

Accordingly, although the there is no consensus about what the BIM dimensions above 5D represent (see section 2.3), according to Kumar, (2019), 8D BIM dimension represents occupational safety and health. These concept means that the 8D BIM dimension entails a safety model that is useful for checking operators' risk and preventing critical hazardous scenarios. According to the Hackitt (2018, pg 35) report, "[a] lack of complete, accurate and maintained building information causes a number of challenges" all of which are safety related challenges. The report recommended a golden thread of information throughout the building lifecycle to improve the safety of the building, residents, and owners. However, BIM was the platform recommended for utilisation to provide the golden thread (BRAC, 2021). In Nigeria, documented building collapse and fatalities are associated with factors such as a lack of safety design and the absence of a systemic approach to assess the integrity of buildings (i.e. test the safety level of a structure). Therefore, the 8D BIM model has the potential to serve as a viable approach to curb building collapse in Nigeria, since it could be utilised to improve the safety of an asset.

Moreover, the application of BIM is numerous especially when combined with other aspects (nD BIM dimension), such as the Internet of Things to collect data from smart devices and perform user behaviour analysis through a machine learning approach (Dave et al., 2018; Hassan et al., 2018; Plageras et al., 2018; Tang et al., 2019). This knowledge could be leveraged to develop a recommendation system which would be beneficial to guiding future design. To affirm this claim, research conducted on nD BIM included integrating blockchain to BIM (Marsal-Llacuna, 2018), an IoT enabled BIM platform for offsite prefabs (Li et al., 2018; Li et al., 2019), and a BIM based fire rescue warning system (Chen et al., 2018).

Overall, BIM is fundamental to digital construction and digital transformation in the construction industry. As such, a BIM approach has continually demonstrated that it possesses the potential to be instrumental in facilitating the mitigation of real-world challenges, particularly those associated with the Nigerian construction industry. Nonetheless, despite the potential benefits and drivers of BIM adoption, the Nigerian construction industry, particularly SMAFs, are yet to fully adopt it due to the barriers they face (Makarfi & Kori, 2018; Saka & Chan, 2021). Thus, in the subsequent section, the discussion of the barriers and challenges that hinder BIM adoption within the Nigerian construction industry is presented.

2.5 Challenges and Barriers of BIM Adoption

Prior to discussing the barriers to BIM adoption, it is important to clarify that some of the drivers mentioned in the previous sections are noted as barriers to its adoption due to the different in study context. As affirmed by Gu & London (2010), BIM adoption studies often vary based on the context. For example, among the top drivers of BIM adoption in the UK is the push from the UK government through their BIM Level 2 mandate (Ahmed & Kassem, 2018), while, in the Nigerian context, the lack of policies to enforce BIM adoption from the Nigerian government is identified as a barrier (S. Babatunde, Ekundayo, et al., 2020). Accordingly, there are several barriers to BIM adoption identified in the literature including cost-related issues, training and knowledge, interoperability, and changes in the design process (Abd Hamid et al., 2018; Bui et al., 2016; W. Hatem et al., 2018; Mohd Sabri et al., 2018; Olawumi et al., 2018; Sardroud et al., 2018; Walasek & Barszcz, 2017). Accordingly, the potential barriers and challenges identified to hinder BIM adoption within the Nigerian construction industry could be clustered under three headings, namely technology, environment, and organisation (Babatunde et al., 2018; Babatunde et al., 2020; Saka et al., 2020). Thus, as shown in Table 2.1, a similar approach is adopted to present the barriers that have been identified as hindering the adoption of BIM in a Nigerian context.

Table 2.1: Challenges and Barriers to BIM adoption in Nigeria

	Barriers	References
	Technological	
1	Relative advantage (increase productivity and performance, reduce overall cost, shorten project duration, mitigate risk)	(Olanrewaju et al., 2020), (Olanrewaju, Kineber, et al., 2021), (Hamma-adama, Kouider, et al., 2018)
2	Compatibility with existing process, culture, and values (ability to produce desired results)	(Saka & Chan, 2020) (Onososen & Adeyemo, 2020) (Wang, 2015) (Ezeokoli et al., 2016) (Olanrewaju, Kineber, et al., 2021)
3	Complexity level to learn and implement in business operations	(Hamma-adama, Kouider, et al., 2018), (Ezeokoli et al., 2016)
4	Tangible measurable benefits (positive evidence of benefits, visualization, ROI)	(Saka & Chan, 2020), (Onososen & Adeyemo, 2020), (Wang, 2015) (Ezeokoli et al., 2016), (Olanrewaju, Kineber, et al., 2021)
5	Interoperability between different platforms (relatively higher interoperability than CAD)	(Olanrewaju, Kineber, et al., 2021), (Ezeokoli et al., 2016)
6	Availability and affordability of BIM tools	(Saka & Chan, 2020), (Onososen & Adeyemo, 2020), (Wang, 2015), (Ezeokoli

		et al., 2016), (Olanrewaju, Kineber, et al., 2021)
	Organisational	
7	Top management support (willingness to support change, encouraging decision and policies, facilitating innovation)	(Saka et al., 2020), (Hamma-adama, Kouider, et al., 2018), (Ezeokoli et al., 2016)
8	Adequate financial resources (adequate budget allocation to facilitate BIM, available & required BIM implementation cost)	(Saka & Chan, 2020), (Onososen & Adeyemo, 2020), (Wang, 2015), (Ezeokoli et al., 2016), (Olanrewaju, Kineber, et al., 2021), (Kori & Kiviniemi, 2015)
9	Organisational readiness (trained employees and BIM champion, capability to provide training, infrastructure, availability of BIM experts, R&D capability, size related to readiness)	(Saka et al., 2020) (Hamma-adama, Kouider, et al., 2018), (S. Babatunde et al., 2018), (Kori & Kiviniemi, 2015)
10	Organisational culture to support BIM (shared motivation, willingness to change, enabling environment, flexibility and adaptability to market)	(Olanrewaju et al., 2020), (Olanrewaju, Kineber, et al., 2021), (Abubakar et al., 2014), (Kori & Kiviniemi, 2015)
	Environmental	
11	Client demanding to use BIM and maintaining the relationship	(Saka et al., 2020), (Olanrewaju, Kineber, et al., 2021)
12	Business partners requesting to use BIM	(Saka & Chan, 2020) (Onososen & Adeyemo, 2020), (Wang, 2015) (Ezeokoli et al., 2016)
13	Government legislative push i.e. mandate and policies	(Saka et al., 2020) (Hamma-adama, Kouider, et al., 2018), (Ezeokoli et al., 2016)
15	Competitive benefits and market trends	(Onososen & Adeyemo, 2020) (Wang, 2015) (Ezeokoli et al., 2016),(Olanrewaju et al., 2020)
16	The BIM norms, standards, and policies motivating an organisation to adopt BIM	(Ezeokoli et al., 2016), (Saka & Chan, 2020) (Onososen & Adeyemo, 2020), (Wang, 2015) (Ezeokoli et al., 2016), (Saka et al., 2020) (Hamma-adama, Kouider, et al., 2018)

2.5.1 Technological Related Challenges and Barriers

The adoption of BIM in the construction industry is catalysed and hindered by several drivers and barriers; some of these drivers and barriers are highlighted by different researchers and listed in Table 2.1. However, Following Rogers (2003) theory of diffusion, BIM related research (Ahmed & Kassem, 2018; Babatunde, Udeaja, et al., 2020; Olanrewaju, Babarinde, et al., 2021; Saka & Chan, 2020) revealed that the potential barriers to BIM adoption within Nigeria include: the perceived usefulness of

BIM (it could be used to simplify work, produce 3D, cost estimation, avoid rework), complexity or ease of use (difficulty level to learn), compatibility with work practices (workflow), a lack of tangible benefits (lack of evidence of a return on investment – ROI, attracting more clients, save cost, competitive edge).

Accordingly, the lack of adequate interoperability and standards between different software vendors is considered a technological related challenge to BIM adoption (Ahn et al., 2016). Interoperability is the ability of an individual BIM compliant software to access and modify a model developed with a different BIM software (i.e. from a different vendor) without any significant data loss (Gimenez et al., 2015). Despite the International Alliance for interoperability (IAI) setting the International Foundation Class (IFC) as a standard for BIM models (Davtalab et al., 2018), literature identified interoperability among the various available BIM software as a significant drawback to BIM adoption (Bueno & Fabricio, 2018; Doumbouya et al., 2018; Fadason et al., 2018; Gimenez et al., 2015; Hamada et al., 2017; Hosseini et al., 2015).

2.5.2 Organisational Related Challenges and Barriers

BIM requires a complete change in the design process, which means shifting the design workload to the early phase of the project (Eastman et al., 2012). Thus, more engineering knowledge and design skills are needed to develop the model at an early design stage (Eastman et al., 2012; Ibrahim et al., 2004; Kaner et al., 2008; Selçuk Çıdık et al., 2017). This resulting shift in the workload distribution structure results in additional fees for professionals for design services necessitating a change in the design provision process (Doumbouya et al., 2018). Although BIM required a change in the process of design and delivery of projects, namely a “paradigm shift process” within the industry, several studies have also identified “resistance to change” as a significant barrier to BIM adoption (Hatem et al., 2018; Liao & Ai Lin Teo, 2018; Matarneh & Hamed, 2017; Mohd Sabri et al., 2018; Olawumi et al., 2018; Sabri et al., 2018).

Furthermore, management support and financially related challenges of BIM adoption in the construction industry such as the initial cost needed to move from traditional 2D or 3D computer-aided design (CAD) approach of design to a BIM approach is considered an essential barrier to SMEs (Hosseini et al., 2015; Monozam et al., 2016). This entails the initial purchase cost of training, the cost of BIM software, and the cost of upgrading the hardware to manage BIM. Although the training and upskilling of staff are requisites for the successful adoption of BIM, they are also among the factors that have high impacts on the total cost of its adoption (Fadason et al., 2018; Hanafi et al., 2016). For SMEs, the financial implications of adopting BIM are important because of their limited resources. Therefore, they are hesitant to adopt it without fully understanding the financial benefits and the ROI it is likely to realise (Kori, 2015). Additionally, the lack of an implementation framework and legal framework hinders SMEs from adopting BIM. As affirmed by Liu et al. (2020), the availability of these frameworks could provide guidance and strategic understanding about the legal and implementation processes required to successfully adopt BIM. Thus, Wang's (2015) ranking of the barriers that hinder BIM adoption in Nigerian firms, revealed that a lack of awareness of BIM technology, technical expertise, high cost of investment on IT infrastructure, staff training, and process change are the most crucial impediments. Therefore, for top management to fully support the transition process to BIM adoption, there is need to develop an organisation's capability and culture through policies, an enabling environment, training, and an IT infrastructure (S. Babatunde et al., 2021). Consequently, developing their capability might be difficult due to limited financial resources and understanding of the BIM process (Kori & Kiviniemi, 2015). This further justifies the need to develop a framework to understand the adoption process of BIM within Nigerian SMAFs in order to effectively allocate their resources.

2.5.3 Environmental Related Challenges

In developed countries, such as UK, Australia and China, their respective governments are already mandating BIM on all centrally public funded projects (Makabate et al., 2021). However, despite the documented benefits realised from adopting BIM in the construction industry, developing countries, such as Nigeria, still lack the support of the government and clients (Saka & Chan, 2019). Additionally, studies (Amuda-Yusuf, 2018; Babatunde, Udeaja, et al., 2020; Saka & Chan, 2020) on BIM awareness in Nigeria revealed that the level of awareness and clear understanding of BIM contributes to the lack of BIM adoption support from clients, the government, professional bodies, and educational institutions. Olanrewaju, Kineber, et al. (2021) recognises the absence of appropriate guidelines as a significant barrier to BIM adoption. However, providing appropriate guidelines needs to be accompanied with regulations to support the desired change process (Ezeokoli et al., 2016). Thus, Babatunde et al. (2020) recognised that the inadequate support of general regulatory bodies and governments to have negative impacts on BIM adoption. Additionally, inadequate regulatory support for BIM usage results in differences in information delivery between various firms (Okolie et al., 2020), thus making the BIM adoption process within firms difficult. In addition to lack of government policies, Baghaei Daemei & Safari (2018) identified the structure of the market and working environment as significant barriers to adoption. In the Nigerian context, since there is no policy or standard procedure to deliver projects, it is difficult to fully collaborate where other professional business partners are yet to adopt BIM (Makarfi & Kori, 2018). This insinuates that the market structure and working environment does not fully support BIM.

Another significant barrier to BIM adoption is the lack of expertise within the industry (Ezeokoli et al., 2016; Okolie et al., 2020). For over a decade, the lack of expertise within the industry has remained identified as a barrier to BIM adoption. According to Underwood et al. (2015), in the UK, the underperformance of Higher Education Institutions (HEIs) and their low engagement level with the industry contribute to the lack of expertise within the industry. Similarly, Nigerian HEIs are technically not ready for BIM training, and therefore, only train students on 2D and 3D CAD file-based collaboration (Hamma-adama, Kouider, et al., 2018). This insinuates that the curricula offered are not preparing students to acquire the skills needed to bridge the industry's lack of expertise.

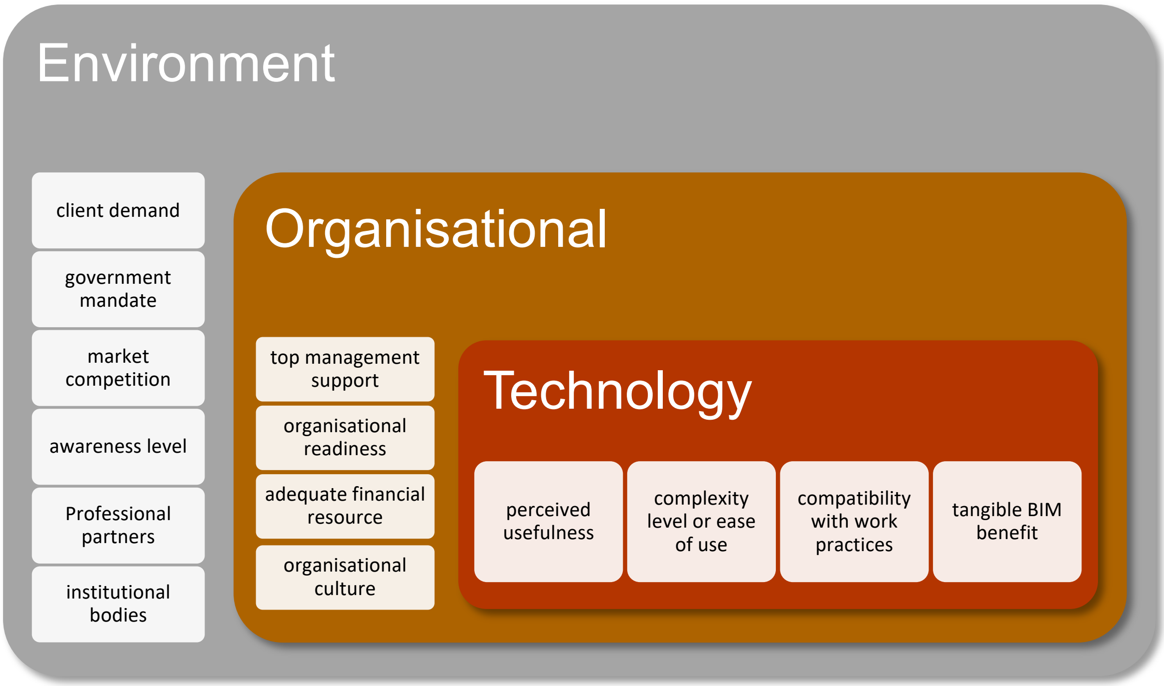


Figure 2.6: Barriers to BIM adoption

Figure 2.6 illustrates a summary of the key barriers to BIM adoption. These identified barriers influence the adoption and implementation of BIM to various degrees within the Nigerian construction industry context. Makabate et al. (2021) affirmed that barriers hindering BIM adoption within large firms differ from the barriers affecting SME's and therefore, suggesting that the actual barriers should be investigated. Based on this suggestion, the identified barriers are considered to influence BIM adoption within Nigerian SMAFs and thus, were a focus when developing the constructs for the conceptual model in the next chapter. However, in the subsequent sections, the status of BIM adoption and implementation globally and within the context of this study (Nigeria) is presented.

2.6 Status of BIM Adoption and Implementation

BIM's potential to offer for radical improvements in the construction industry is recognised worldwide. Initially identified as a new wave of project visualisation and coordination techniques, BIM is now seen as a paradigm shift. This process-based methodology enables collaborative work on construction projects, offering many benefits to facility management and beyond from the initial stage. According to Kouch (2018), the three levels of BIM implementation are: Micro (inside the organisation), Meso (within the project), and Macro (market/national). Micro level BIM implementation relates to organisational (institutional) implementation, with the company's top management approving BIM use (Papadonikolaki 2018; Succar 2010). As stipulated by the owner and project manager, the accreditation based on projects and their teams is the Meso level implementation of BIM (Succar 2010; Papadonikolaki 2018). Governments and international organisations are involved in macro level BIM adoption, which is linked to markets and industries (all over the country) (Succar 2010; Papadonikolaki 2018).

Several research projects, reports and industrial surveys have shown that BIM is successfully used in most industrialised countries. For example, Jung & Lee (2015) conducted a survey study on the status of BIM adoption on six continents. The outcome of the study revealed that North America was the most advanced continent, followed by Oceania and Europe; this was based on their BIM engagement level (i.e. depth of implementation, years of using BIM and proficiency level). Thus, the subsequent section further explains the macro level BIM adoption process by focusing on the United States (as pioneers of BIM adoption), the United Kingdom (as the champions of BIM standards) and Nigeria (as the context of this research).

2.6.1 The United States of America

The United States was among the pioneers of BIM adopters and is often considered an inspiration for other countries to follow when introducing and practicing BIM (Jung & Lee, 2015; Lee & Yu, 2016; Saka & Chan, 2019). In 2003, the US General Services Administration (GSA) created a national 3D-4D BIM policy (General Services Administration (GSA), 2021). This policy program was apparent in the government's push for digitised construction industry. The policy program's goals were as follows:

- Create a policy that requires all large projects to use 3D, 4D, and BIM.
- For existing and future capital projects, lead 3D-4D-BIM prototype applications and incentives.
- Expert advice and evaluation for ongoing capital projects incorporating 3D, 4D, and BIM technology.
- Examine the readiness and technological maturity of the industry
- Collaborate with open standard organisations, professional groups, BIM vendors and academic/research institutions.
- In 2007, the GSA enforced BIM usage in all new projects (Wong et al., 2011).

Architects, engineers, MEP, contractors, subcontractors, and customers are among the essential stakeholders in the US construction industry. Within the construction industry in the United States, architects appear to be a primary driver for innovation. The “Chief Architect,” Public Buildings Service, is the title given to the head of the General Services Administration (GSA, 2021). Before the 2003 GSA guidelines, architects were already using BIM tools and techniques.

In the United States, the digitalisation in the construction industry began in the 1990s with the International Alliance for Interoperability (IAI), which later became buildingSMART (Edirisinghe et al., 2017). The National BIM strategy and mandate followed in 2003 and 2007. In the United States, the industry has been leading the way in terms of innovation. The American Institute of Architects actively promoted the BIM concept, making it easier for the federal government to participate. In 2007, the government passed legislation to make it legal. The BIM diffusion mechanism in the United States looks to be “middle-out” (Kassem & Succar, 2017), although there was previous evidence of a “top-down” strategy due to the engagement of government agencies and large clients (Kassem et al. 2014).

The mandates of state governments have fuelled a growth in BIM implementation in the United States (Smith 2014). Contractors indicated significant benefits from embracing BIM (Construction 2014); similarly, the high adoption rate was driven by the fear of being left behind if one did not adopt the BIM revolution. It was simpler to formulate and implement laws because the industry was comparatively developed (led by the American Institute of Architects) before the governments’ policies were introduced. As a result of prominent organisations’ and industry associates’ (i.e. AIA) involvement, BIM development in the United States was termed a middle-out diffusion dynamic (Kassem et al., 2013).

The United States was among the early adopters of BIM (Jung & Lee, 2015) and therefore, the process was laborious and sometimes unpleasant (Hamma-adama & Kouider, 2019; Manzoor, Othman, Gardezi, et al., 2021). Despite this, the United States persevered in learning from their challenges and, in the end, developed better solutions (Hamma-adama, Salman, et al., 2018). Nations that were slower to embrace BIM could evade some of the challenges that the United States faced, resulting in a more efficient and faster process (Ying et al., 2020). As a result, some countries have matched or even exceeded the United States in BIM adoption and standards development (e.g. the United Kingdom).

In the United States, there is no clear national standard or mandate for project delivery when using BIM (Lee & Yu, 2016). Due to the lack of a national standard and mandate, open-deliverables become dependent on client-to-client or even project-to-project. Various government agencies in the United States develop (independently developed) standards and publish them in places like the National Institute of Building Sciences (NIBS).

The policy is thought to have aided in the rapid acceptance of BIM at the design stage, particularly among architects; as a result, architects were found to be advocating post-policy BIM use in the United States, while clients trailed behind (Edirisinghe et al., 2017). Even though BIM has a proven track record in the building business in the United States, owners are still lagging (Costin et al., 2018).

The US General Services Administration (GSA) launched the National 3D-4D BIM Program through the chief architect's office and public building services shortly after Autodesk bought Revit Technology Corporation (2002). Following that, BIM technology use began to spread across the United States, and in 2007, BIM became mandatory in all final concept approval for all significant projects. All GSA projects were mandated to use 3D, 4D, and BIM technology, which the GSA BIM Guide Series supported (GSA, 2021). BIM adoption almost doubled in two years after the BIM Guide Series (2009) release, compared to the start-up rate of 28% in 2007 (GSA, 2021). Many National Building Information Modelling Standards (NBIMS) have been published by NIBS, focusing on building energy performance (Edirisinghe & London, 2015).

The United States is regarded as a technological development hotspot, with the availability and affordability of technology propelling the public and private sectors to the top of the global rankings (Jung & Lee, 2015). Even before the government requirement in 2007, the availability of IT infrastructure helped the rapid development, adoption, and application of BIM throughout the industry (Mustaffa et al., 2017). That is what drives competition and massive growth across the board.

2.6.2 The United Kingdom

The United Kingdom (UK) Government created a task group to help government clients and supply chain providers migrate to BIM and digital delivery in an inclusive digital economy (Digital Built Britain). The strategy's overall purpose is to increase the efficiency of public real estate by lowering capital costs and lowering carbon dioxide emissions. Furthermore, it aspires to be a global leader in BIM and digital transformation (BIM Industry Working Group 2011). Architects, engineering professionals, contractors, subcontractors, and clients are the primary stakeholders in the construction industry. Clients are the driving force behind the industry in the UK. However, clients were cautious and diverse until the industry's recent development; Latham (1994) illustrates that different government departments had distinct procurement strategies (Latham 1994). Furthermore, contracts primarily in traditional form (i.e. standard formats like JCT 80 or ICE 5/6) were considered unsuitable for collaborative working. In the UK construction industry, the five different contractual systems used are: traditional contracts, construction management, management contracts, management and design contracts, and design and build contracts. However, according to Shaiste (2015), one is favoured over the other in a digital transformation strategy. This strategy seeks to accomplish this transformation by facilitating new digital organisations or assisting traditional organisations in their digital transformation (Shaiste, 2015).

In 2008, Bew and Richards established a BIM maturity wedge indicating maturity levels which range from zero (0 – paper based) to three (3 – integrated web-based). Among the three BIM maturity levels, the UK government mandated BIM maturity Level 2 on centrally public procured projects prior to the launch of the EN ISO 19650 series. The British Standards Institution (BSI) defines Level 2 BIM maturity as a set of domain and collaborative federated models prepared by many stakeholders throughout the project life cycle using 3D graphical and non-graphical data in a shared data environment. BIM receives considerable attention in the United Kingdom as a result of the government's commitment. In 2011, the UK government's directive for all major government projects over £5 million to enable Level 2 BIM by 2016 represented a significant step forward. However, according to UK BIM Alliance (2021), approximately 65% of organisations are aware and implementing BIM in their projects, while only 5% are unaware. Additionally, according to NBS (2020), the use of BIM has significantly risen from 13% in 2011 to 73% in 2020. The UK Government's 2016 Tier 2 BIM Authorization Policy accelerated the deployment of BIM models in the country. During the five years preceding the mandate's expiration date (2016), a significant increase (from 31% to 62%) was observed. Government initiatives have increased adoption, with evident 'top-down' diffusion dynamics (Succar & Kassem

2015), which is now the dominant strategy for BIM adoption in the United Kingdom, as documented by the Government Building Group (2011). Following further research, the approach was modified (midway) in response to the greater adoption by larger organisations, establishing them as a leader in furthering adoption. According to NBS (2020), in the UK, the use of BIM on private projects is 77% while BIM usage on public projects is 62%. This indicates that the private sector is leaping ahead of the public sector in terms of the BIM usage on projects (NBS, 2020). The UK BIM implementation strategy is a 'Push-Pull' type where 'Push' is a five-year horizon given to the industry's supply-side to get all players that have reached Level 2 BIM. While the 'pull' credit comes from the customer side to identify, collect and use information created (BIM Industry Working Group 2011).

The availability of notable BIM publications (i.e. standards, protocols and documentations) played an essential role in accelerating owners' BIM engagement (Edirisinghe and London 2015). Despite the government mandate, the digital transformation and BIM has faced some challenges, such as a lack of inhouse skills/expertise and training; which remain the two main barriers (Underwood et al., 2021). In addition, Dainty et al. (2017) reported the lack of clearly defined capacity in UK policy on BIM adoption as an impediment to its adoption. Accordingly, the targeted benefit of this digital transformation, on the other hand, is: greater efficiency, lower total life cost assets, lower carbon footprint, and improved construction information storage and management capability (Underwood et al., 2021).

Furthermore, education and training are lagging, despite various attempts to take advantage of UK educational programmes, such as BIM for education and BIM for SME's (Uhm et al., 2017). In BIM education, architecture schools are ahead of all other majors in the built environment (Prabhakaran et al., 2021). However, despite the commitment of organisations to support BIM training within the industry, there is a lack of proper guidance in BIM education and training within the industry (Liao & Teo, 2018). Thus, researchers such as Semaan et al. (2021) investigated an organisational upskilling model that could potentially provide guidance on work based education and training for effective BIM adoption.

The UK BIM Framework is the overarching approach to implementing BIM in the UK, led by BSI, CDBB and the UK BIM Alliance (Fitz, 2020). It is the UK's version of the ISO 19650 series, with the UK Addendum (UKBIM Framework, 2021). The EN ISO 19650, which comes with a transition guidance (PD 19650 2019) document, superseded the PAS 1192 series of standards (developed by UK BIM Task Group) which defined a workable explanation of the critical exchange points between the client and supply chain at various building project stages, focusing on stage 2 BIM compliance (UKBIM Framework, 2021).

According to BIM Wiki (2021), the BS EN ISO 19650 – 1 : 2018 published in January 2019 outlines the concepts and principles, and provides recommendations on how to manage building information while, the BS EN ISO 19650 – 2 : 2018 supplies information management requirements in the delivery phase of assets. BS EN ISO 19650 – 3: 2020 involves the operational phase of the assets while BS EN ISO 19650 – 5: 2020 outlines the security minded approach to information management using BIM. Accordingly, the following represents the UK BIM framework:

1. **PD 19650-0:2019:** Transition guidance to BS EN ISO 19650
2. **BS EN ISO 19650-1:2018:** Concepts and principles
   Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM). Information management using building information modelling.
3. **BS EN ISO 19650-2:2018 & Revised NA:** Delivery phase of the assets
   Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM). Information management using building information modelling.
4. **BS EN ISO 19650-3:2020:** Operational phase of the assets
   Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM). Information management using building information modelling.
5. **BS EN ISO 19650-5:2020:** Security-minded approach to information management
   Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM). Information management using building information modelling.
6. **BS 1192-4:2014:** Code of practice
   Collaborative production of information - fulfilling employer's information exchange requirements using COBie.
7. **PAS 1192-6:2018:** Specification for collaborative sharing and use of structured Health and Safety information using BIM
8. **BS 8536-1:2015:** Briefing for design and construction - Code of Practice for facilities management (Buildings infrastructure)
9. **BS 8536-2:2016:** Briefing for design and construction - Code of Practice for asset management (Linear and geographical infrastructure)

Conclusively, the EN BS ISO 19650 series has the potential to facilitate delivery teams consisting of organisations from different countries with different cultures and different ways of working to adopt a simplified and standard approach to managing information. Therefore, the Nigerian construction industry can benefit from the ISO standard to align industry practice with international benchmarks and gain a competitive advantage. Thus, the following sections discuss BIM adoption in the Nigerian context.

2.6.3 BIM in the Nigerian Context

Over the years, several BIM related studies within the context of the Nigerian construction industry have been conducted. However, to understand the trend and give an overview of current studies, a literature review was conducted and presented (see Appendix 3: BIM Research in the Nigerian Context).

In Nigeria, there is little awareness of and expertise in BIM technology (Onungwa et al., 2017); this is often attributed to a lack of awareness of the concept, or a lack of BIM skills amongst employees, or both (Abubakar et al., 2013; Onungwa et al., 2017). According to Kori (2015), large enterprises are driving BIM implementation in the Nigerian construction industry. However, small and medium firms lag in BIM adoption due to their low adherence to policy and process. On the other contrary, the current adoption is traceable at an organisational level known as a “lonely BIM” (Hamma-adama et al., 2017) and operated at Stage 1 BIM. The Nigerian construction industry is essentially fragmented: all specialists generate and manage information separately (Onungwa et al., 2017). Therefore, the industry culture is quite traditional, necessitating behavioural adjustment (Hamma-adama et al., 2017; Kori, 2015). However, according to Hardin and McCool (2015), behavioural change, which involves modifying processes and perception, is the most challenging change required for successful BIM adoption. However, to alter the behaviour of Nigerian building industry professionals, awareness or a basic understanding of the BIM concept is required (Hamma-adama, Kouider, et al., 2018). Thus, this research aims to develop a framework to understand BIM adoption within Nigerian SMAFs to facilitate the adoption of BIM.

Consequently, prominent BIM research in Nigeria revolves around assessing the training gap of BIM among Nigerian construction professionals (Onososen & Adeyemo, 2020; Oyewole & Dada, 2019), assessing BIM uptake in managing construction projects (S. Babatunde et al., 2021; Ojelabi et al., 2019; Ugochukwu et al., 2015), analysing the drivers and barriers of BIM in Nigeria (S. Babatunde et al., 2018; Olanrewaju, Babarinde, et al., 2021; Saka et al., 2020), investigating the level of BIM awareness among Nigerian construction industry professionals (S. Babatunde et al., 2021; Ibem et al., 2018), ranking the critical factors of BIM implementation (Amuda-Yusuf, 2018; Usman et al., 2016), and evaluating BIM diffusion (Hamma-adama, Kouider, et al., 2018; Hamma-adama, Salman, et al., 2018) among others.

The Nigerian construction industry is the largest in West Africa using a diverse skilled and unskilled workers (Olanrewaju et al., 2021; Saka et al., 2020). However, the industry is yet to fully implement BIM due to its sluggish nature when responding to emerging changes. Olanrewaju et al. (2021) reported that the level of awareness among professionals is below average (40%). This could be attributed to the lack of support from the government, regulatory bodies, and educational institutions (Hamma-adama et al., 2018). Additionally, Olanrewaju et al. (2020) and Usman et al. (2016) affirmed that government-related factors, such as not taking the initiative to formulate and enforce policies that control BIM implementation, are still among the main factors. Furthermore, Onungwa & Uduma-Olugu (2017) corroborated that there is low awareness of and technical expertise in BIM within the Nigerian construction industry. On the other hand, the assessment by Onungwa et al. (2017) on the impact of BIM usage on construction management reveals that building professionals were aware of BIM benefits for construction planning, the supervision of jobs, the quality of completed jobs and energy efficiency. Nonetheless, the study revealed that the main factor hindering BIM adoption was cost estimation, and safety was not achieved through BIM. Thus, Onungwa et al. (2017) suggested that developing processes and standards incorporating BIM from regulatory bodies would be a prerequisite to its full adoption.

Conclusively, although significant research efforts have been made to increase the adoption level of BIM, studies still recognise a significantly low adoption within the Nigerian industry. Therefore, recommendations were made towards improving adoption within the industry such as “developing an all-in-one blueprint for adoption through awareness and training by developing an effective adoption framework” (Hamma-adama et al., 2018, pg 342). Considering that Nigerian SMAFs are struggling with the cultural transformation towards BIM practices due to their lack of understanding of BIM adoption processes (Kori & Kiviniemi, 2015), it is important to establish a framework to understand the various factors that are crucial to the successful adoption of BIM within Nigerian SMAFs.

2.6.4 COVID Impact on BIM Adoption

In the pre-COVID-19 context, the BIM market had seen an increase in demand. Increased housing and infrastructure development needs are projected to fuel the growth of the worldwide construction sector, producing a considerable demand for BIM from construction professionals as populations and global economies grow. Growing trends in modern technology have resulted in a rise in the use of new methods to labour standards in the construction industry. BIM is one approach that offers benefits, such as visualisation and collaboration, construction design and planning synchronisation, conflict identification, and cost reduction. While these reasons will always contribute to BIM's market growth, it will fall short of its prior expectation of $9.5 billion by 2025, with a CAGR of 12.7% from 2020 to 2025 (MarketsandMarkets, 2020).

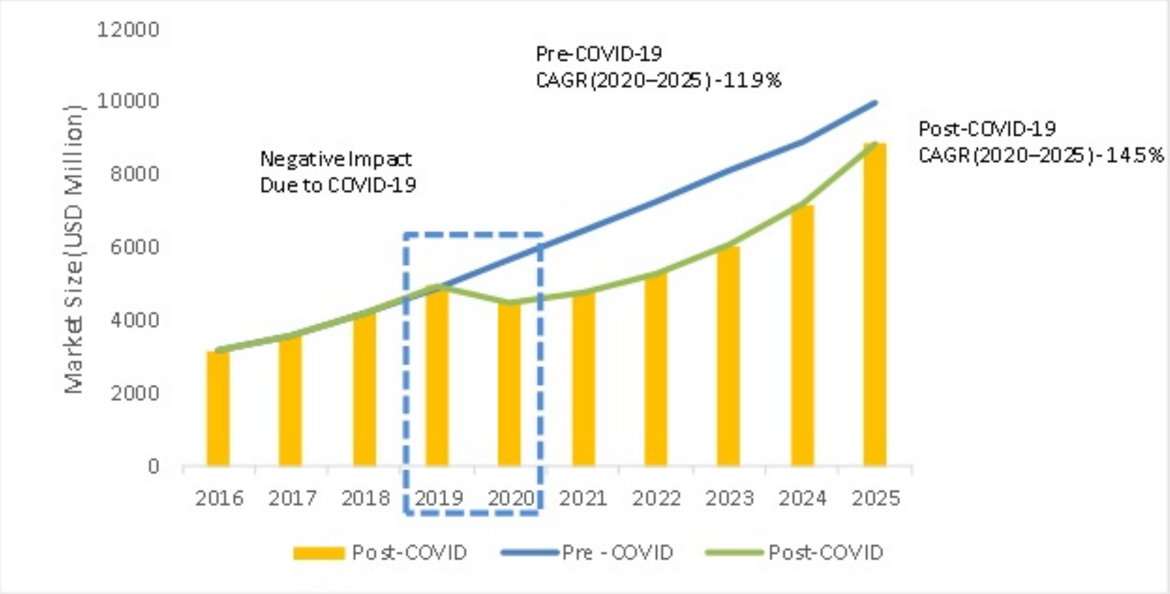


Figure 2.7: COVID-19 Market Outlook
Source: (MarketsandMarkets, 2020)

Figure 2.7 suggests that the market is predicted to steadily recover over the next two years, reaching $8.8 billion by 2025, with a CAGR of 14.5 percent from 2020 to 2025. The COVID-19 virus outbreak in December 2019 resulted in the virus spreading rapidly to approximately 100 nations worldwide. It has been labelled a public health emergency by the World Health Organization. MarketsandMarkets (2020) reports that the total BIM market is projected to suffer as a result of COVID-19. According to the Associated General Contractors of America (AGC), at least 45% of contractors are suffering delays or disruption as a result of the outbreak (AGC, 2021). The scarcity of building materials, parts, and equipment is causing these delays. Aside from that, a scarcity of experienced personnel and construction safety equipment are two main issues plaguing the industry. Furthermore, some construction projects are suspended or delayed due to asymptomatic workers, as temporary closure is required if a person tests positive. In the Nigerian context, Osuizugbo (2021) revealed that logistical challenges (i.e. both the construction material and construction workers), project abandonment, and delays in construction activities are among the negative impacts of the pandemic on the Nigerian construction industry. The lesson learnt based on the impact of COVID-19 on the construction industry is the need to improve the construction supply chain and project management, by focusing on an effective virtual working environment, and improving occupational/onsite health and safety measures (Ogunnusi et al., 2021). In this regards, BIM is useful to enhance COVID-19 compliance on construction sites (A.-Q. Gbadamosi et al., 2020), and informing key stakeholders on the creation of an enabling working environment (Ebekozien & Aigbavboa, 2021).

2.7 Chapter Summary

This chapter has reviewed the construction industry through the Nigerian context, and consideration has been given to the characteristics and challenges of the industry. Nigeria is an emerging economy and occupies a significant position in Africa. Although the Nigerian construction industry is essential for boosting the country's economy, the industry still faces significant challenges, including limited access to funds, substandard construction data, poor managerial skills, limited technical skills, a lack of transparency, and poor land administration policies, and inadequate regulation. All these challenges ultimately result in inefficiency, low productivity, delays in project delivery, and a high level of project failure. Against this background, there is a need to improve practices within the industry. Therefore, this study hopes to respond to this need, aiming to achieve a marked shift towards more effective and efficient project delivery methods and practices. Whilst this chapter discussed the construction industry from the Nigerian context, it also explored the current state-of-art of BIM in the US, UK and Nigeria. The chapter also presented the definition, concept, dimensions, benefits and drivers, challenges and barriers, and standards of BIM. However, looking at the adoption status globally and the Nigerian context, the need to align the Nigerian construction industry to the international benchmark is apparent. Additionally, the chapter demonstrated that, although BIM has strengthened its position in bringing efficiency to the construction industry, the shift to its adoption and implementation in emerging markets is challenging, particularly for Nigerian SMAFs due to their limited resources to absorb the initial costs associated with such a shift. Thus, providing a framework to understand the BIM adoption process and factors influencing its adoption within Nigerian SMAFs will alleviate the barriers within the Nigerian construction industry. Nonetheless, this chapter provided a fundamental understanding of the Nigerian construction industry and BIM adoption, while the next chapter establishes the conceptual model for this research by contextualising the various BIM related theories, models, and frameworks, and by synthesising the various factors that influence adoption. The conceptual model established in the next section guides the empirical enquiry stage in this research. However, the outcome of the empirical enquiry stage will facilitate the development of the framework to understand the BIM adoption process, as well as the factors that influence BIM adoption within the context of Nigerian SMAFs.

3 Chapter Three – Conceptual Framework

3.1 Chapter Overview

This chapter discusses the theoretical formulation of the study, a step in the development of the conceptual model that contains all the relevant factors that contribute to the research problem (i.e. facilitating the empirical enquiry and the development of the framework). The conceptual model considered all information synthesised from the literature review phase in a logical manner. This chapter will, therefore, help to: (i) guide the empirical enquiry of the study and (ii) design a conceptual model for the study by identifying and explaining the research question and variables. In this context, the conceptual model visually presents the key concepts, ideas and constructs that influence BIM adoption and their relationships but does not empirically explain the extent to which the constructs influence BIM adoption. However, the conceptual model will assist in evaluating the constructs and providing empirical evidence of their relationship with BIM adoption within Nigerian SMAFs (i.e. during the empirical enquiry stage). The outcome of the empirical stage will enable the development of the final framework. Thus, as shown in Figure 3.1, this chapter is divided into three sections as follows:

1. The first section focuses on the different theories related to BIM adoption that informed the development of the conceptual model.
2. The second section establishes the structure of the conceptual model that provides an insight into the relationships between the variables within the conceptual model.
3. The third section presents the process of developing the conceptual model by defining the various constructs.

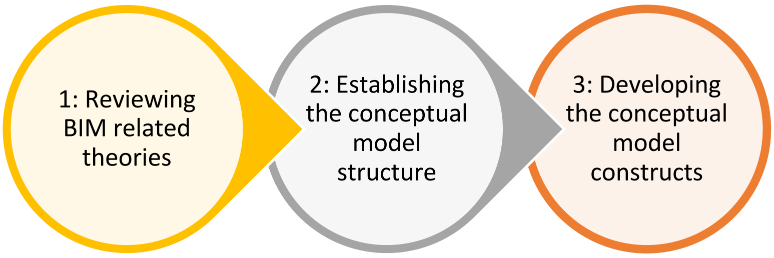


Figure 3.1: Development Process of the Conceptual Model

Thus, this chapter highlights the essential features (i.e. the development process, category classification, and criteria structure) to develop a comprehensive framework for understanding the BIM adoption process within Nigerian SMAFs. The development process of the conceptual model will also guide the development process of the framework for understanding BIM adoption within the Nigerian SMAFs. In this regard, the following section presents a review of BIM adoption-related theories and frameworks.

3.2 Review of Theories adopted from BIM Related Frameworks

In recent decades, there has been an unprecedented increase in the adoption of technology related publications to help organisations and companies improve their competitiveness and innovation. For example, technology adoption models (TAM) allow decision-makers to accept or reject an innovation or assess to what extent it fits the context (Davis, 1989; Hong et al., 2019) whilst innovation diffusion models (IDM) deal with the diffusion of innovation in society (Folkinshteyn & Lennon, 2016; Oliveira & Martins, 2011; Rogers, 1995). As discussed in the previous chapter (see section 2.7), BIM implementations occur at different levels, namely from industry to organisation to project level. However, at the organisational level, these models are typically studied in terms of the individual characteristics of the leader, the internal characteristics of the organisational structure and the external characteristics of the organisation (Rogers, 1995; Oliveira et al., 2011). However, as shown in Figure 3.2, among the reasons for poor industry-wide BIM adoption are obstacles to the effective implementation of BIM at the organisation level, such as ill-informed organisations (Ahmed, 2018). This means that alleviating the lack of information about the BIM adoption process within the organisation by developing a framework to understand BIM within Nigerian SMAFs at the organisational level will impact industry-wide adoption. Therefore, the primary objective is to develop a framework to understand BIM adoption within Nigerian SMAFs. Furthermore, the focus is at the organisational level, as the research is concerned with Nigerian SMAFs. Hence, in Figure 3.2*,* the research context is indicated as the organisation level (Meso).

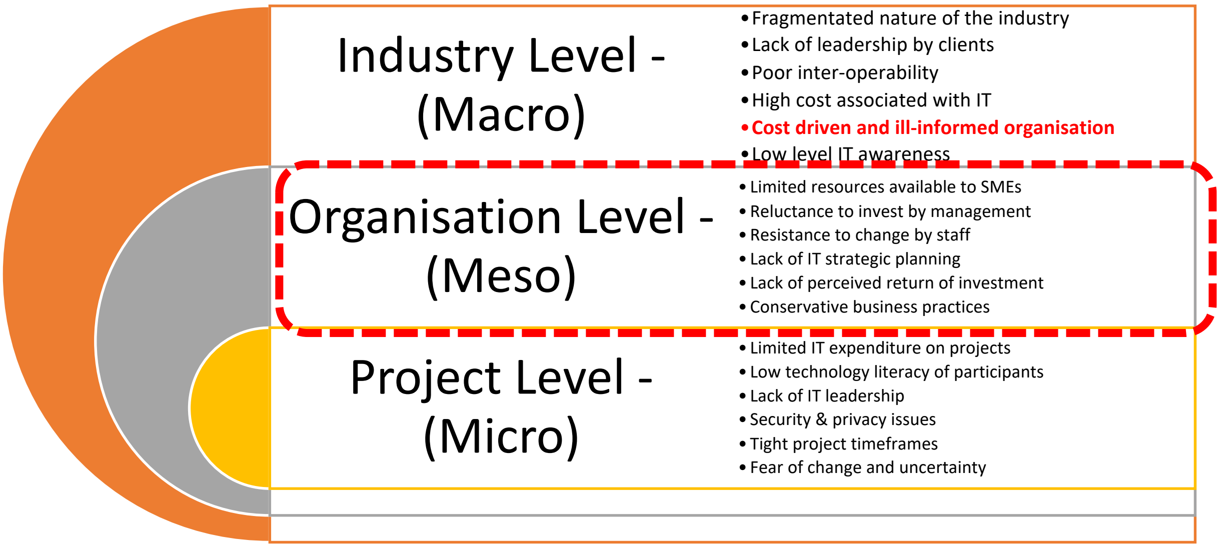


Figure 3.2: BIM Implementation Levels

BIM has become a phenomenon within the construction industry that has attracted governments globally (Adekunle et al., 2021; Saka & Chan, 2019; Saka & Chan, 2021). BIM appears to be moving construction into a new chapter by replacing traditional project working methods with collaborative and coordinated procurement (Kocakaya, 2019; Sacks, Eastman, et al., 2018). In line with the legal requirements of BIM accreditation by governments (McGraw Hill, 2014), numerous investigations have been conducted on BIM to support its application to projects within the construction industry worldwide. Badrinath et al. (2016) found that over the past 25 years, there have been more than 1,500 publications on this type of BIM by researchers from 65 countries. In terms of the research focus of these studies, relatively few publications address the introduction of organisations; this is addressed in only 6% of BIM publications worldwide (Badrinath et al., 2016). This has contributed to the lack of criteria and frameworks to analyse the risks and opportunities of BIM implementation in project implementation, especially for SMEs, which leads to lower BIM adoption rates (Kouider & Paterson, 2013; Lam et al., 2017). However, according to a recent study (Saka & Chan, 2019), there has been a surge in BIM adoption and implementation related research. Therefore, it is vital to take advantage of the available BIM theories and frameworks because a great deal of knowledge and understanding can be gained by analysing the theories and contributions, assessing their limitations, and understanding how the frameworks are developed, validated and shared with users (Succar, 2009). Against this background, the following section presents the reviewed BIM adoption-related theories that could be adapted to guide and inform this research, contribute to expanding the current theoretical knowledge within this research area, and provide clarity to practitioners.

3.2.1 Theories Related to BIM adoption

This section started with a review of BIM-related theories in order to analyse the IS/BIM adoption process. Table 3.1 describes the prominent theories adopted in developing BIM frameworks. Among the prominent theories are Innovation Diffusion Theory (IDT), Institutional Theory (INT), Technology Acceptance Model (TAM), Technology Organisation Environment (TOE), and System Innovation Approach (Ahmed & Kassem, 2018; Ahuja et al., 2020; Howard et al., 2017; Qin et al., 2020). These theories were combined to develop the conceptual model for this research (Table 3.1).

Table 3.1: Conceptual Model of Relevant Theories

(adapted from Murguia et al., 2021)

Theory	Description
Systems theory (Bertalanffy, 1969; Forrest, 2018)	System theory is an entity with interrelated and interdependent parts; it is defined by its boundaries and is more than the sum of its parts (subsystem). Changing one part of the system affects other parts and the whole system, with predictable behaviour patterns. Furthermore, the individuals working as part of a system are components as well, therefore contributing to its outcome. The system theory approach would help to conceptualise BIM adoption process model as an innovation that needs the simultaneous involvement of all actors in the construction industry to achieve the benefits of adoption. Therefore, the conceptual model consists of different parts (categories) that are interrelated and essential to the BIM adoption process within Nigerian SMAFs. The individual parts form a system consisting of components (construct) working as part of the model, and therefore contributing to the overall outcome.
Technology, Organisation and Environment (TOE) Framework (Tornatzky and Fleischer, 1990)	TOE identifies three categories that influence the adoption of technological innovations in organisations: technological determinants, organisational determinants, and environmental determinants. The adoption of technologies sits at the intersection of these factors. The TOE framework is helpful to understand BIM adoption and has been used in previous studies (Chen et al. 2019; Mahamadu et al. 2014). Nonetheless, the TOE model does not clearly distinguish between the role of top managers and final adopters of the innovation (i.e. users) in the adoption process (Murguia et al., 2021). Therefore, the category of individuals (i.e. employees and managers) as the actors needed to adopt BIM within a firm (i.e. Nigerian SMAFs) cannot be captured.
Diffusion of Innovations (DOI) (Rogers, 2003)	DOI presents the innovation-decision process (knowledge, persuasion, decision, implementation, and confirmation) and the attributes of innovations that influence its rate of adoption (relative advantage, compatibility, complexity, trialability, and observability). The attributes of the innovation are crucial to understanding how actors make sense of innovations such as BIM. However, DOI does not clearly distinguish between the decision-maker (at the organisational level) and the user (at the operational level). Moreover, DOI is not a sufficient model to explain different analytical levels of the BIM adoption process as a system theory approach.
Technology Acceptance Model (TAM) (Davis, 1989)	TAM is one of the most influential models of technology acceptance. The model was developed to predict individuals' technology acceptance in terms of their attitudes, subjective norms, perceived usefulness, ease of use, and related variables. TAM provides a useful framework for studying the intention to adopt information systems and actual use. However, the model has been criticised for its narrow focus on individual perception and the lack of vision of technology in a business or organisational context.

Unified Theory of Acceptance and Use of Technologies (UTAUT) (Venkatesh et al. 2003)	The Unified Theory of Acceptance and Use of Technology (UTAUT) predicts factors influencing information systems 'Behavioural Intention' and 'User Behaviour'. It is a unified model of the adoption of technologies at the operational level. UTAUT provides a unified framework for studying the user layer of systemic BIM adoption. However, UTAUT should be adapted to account for other aspects of BIM rather than software adoption. Moreover, UTAUT does not account for the context in which the technology is deployed.

3.3 Establishing the Conceptual Model Structure

Conceptual models are utilised in many domains, including science, socioeconomics, social science and software development, to abstractly describe social or physical aspects of the world (Airbrake, 2017). According to Elangovan & Rajendran (2015), a conceptual model represents or explains the functioning and mechanics of an idea or thought, which is developed in a logical manner to provide rigour to the research process, and is usually highly simplified. Therefore, the conceptual model provides a simplified and logical overview of the relationship between its key concepts. Additionally, Mulder (2017) describes a conceptual model, also called a research model or conceptual framework, as a visual representation that helps to illustrate the expected relationship between the cause and effect of the constructs, which, in this context, influences BIM adoption within Nigerian SMAFs. However, DifferenceBetween.com (2013) highlighted that the model explores the specific methodology of the research, while the framework gives the overall structure of the project. Therefore, the conceptual model focuses on presenting the connectivity amongst aspects of research.

In this research, the purpose of reviewing the theories adopted when developing BIM frameworks is to dovetail the theories to fit the context of Nigerian SMAFs. The outcome of these processes is the conceptual model for this research evaluation. Furthermore, by leveraging the SMAF's ability to absorb BIM quickly due to their flexible organisational structure (Hochscheid & Halin, 2020; Lam, 2011; Papadonikolaki & Aibinu, 2017), the conceptual model would help to develop a framework to understand BIM adoption within Nigerian SMAFs. Thus, this section establishes the conceptual model structure.

From Table 3.1, leveraging the system theory approach, the conceptual model consists of different parts (categories) that are interrelated and essential to the BIM adoption process within Nigerian SMAFs. These individual parts are a system consisting of components (constructs) which working as part of the model and contribute to the overall outcome. Therefore, the system theory approach will guide the process of establishing the conceptual model structure.

Innovation attributes are crucial to understanding how actors make sense of innovations such as BIM (Hamma-adama, Salman, et al., 2018). Therefore, previous research, such as Gholizadeh et al. (2018); Hosseini et al. (2016); Howard et al. (2017); Saka & Chan (2021); Succar & Kassem (2015), and Wang & Lu (2021), explain the diffusion of BIM through the five *stages of innovation adoption* (knowledge, persuasion, decision, implementation, confirmation). However, DOI does not clearly distinguish between the decision-maker (at the organisational level) and the user (at the operational level) (Murguia et al., 2021). Additionally, developing the conceptual model just on DOI theory is insufficient since this theory does not reflect the innovation (BIM) adoption stages as a system theory method.

TOE identifies three categories that influence the adoption of technological innovations in organisations: technology determinants, organisation determinants, and environmental determinants (Tornatzky and Fleischer 1990). Based on Chen et al. (2019), the following factors are catalogued in the TOE framework for BIM adoption: *Technology determinants* (relative advantage, compatibility, complexity), *Organisational determinants* (management support, organisational readiness), and *Environmental determinants* (competitor pressure, customer pressure, partner pressure, government pressure). However, similar to DOI theory, TOE models do not clearly distinguish between the role of top managers and the final adopters of the innovation (i.e. users) in the adoption process (Murguia et al., 2021).

TAM is one of the most popular technology acceptance models (Ahmed & Kassem, 2018). The model was developed to predict *individuals*' *technology* acceptance regarding their attitudes, subjective norms, perceived usefulness, ease of use, and related variables (Davis, 1989). Several BIM studies have utilised the TAM to evaluate technology acceptance. TAM provides a valuable framework for studying the user's intention to adopt information systems or BIM and actual use (Hong et al., 2019; Lee et al., 2015; Lee & Yu, 2017; Sanchís-Pedregosa et al., 2020). However, the model has been criticised for its narrow focus on *individual perception* and the lack of vision of technology in a business or organisational context (Murguia et al., 2021). This means that, as TAM captures only the *technological category* and user's intentions, it alone would be insufficient to develop the conceptual model. Therefore, combining TAM with other models, such as DOI and TOE, would alleviate the limitations and complement the drawbacks of the theoretical models when adopted in isolation.

The Unified Theory of Acceptance and Use of Technology (UTAUT) predicts factors that influence information systems' 'Behavioural Intention' and 'User Behaviour'. It is a unified model of the adoption of technologies at the operational level. This means that UTAUT provides a unified framework for studying the *user layer* (*individual category*) of systemic BIM adoption. However, *UTAUT should be adapted to account* *for other aspects of BIM* rather than software adoption (Murguia et al., 2021). Moreover, UTAUT does not account for the context in which the technology is deployed.

Based on these models, four categories emerge as crucial in developing the conceptual model, which are: *technology, organisation, environment* and *individual*. Furthermore, the stages of BIM adoption, including knowledge acquisition, persuasion strategy, decision making, implementation process, and confirmation or continuation, are crucial to understand the BIM adoption process within Nigerian SMAFs (Makarfi & Udeaja, 2018). In the context of this research, these stages of BIM adoption (based on the DOI concept) are used to evaluate the relationship between the factors that influence BIM adoption and the adoption process within Nigerian SMAFs at the qualitative investigative stage. The outcome of this stage will form part of the final framework development to understand the BIM adoption process within Nigerian SMAFs. Therefore, considering these components, the following section elaborates on each category. Figure 3.3 shows the conceptual model constructs, including the four categories of factors that influence BIM adoption and the five adoption process stages applied to this study.

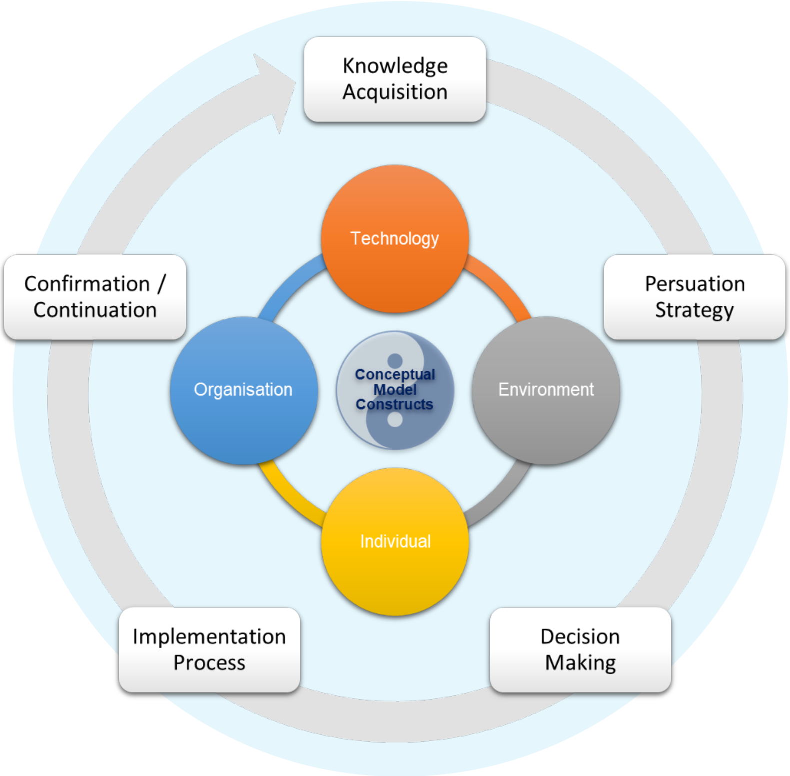


Figure 3.3: Conceptual Model Categories and Adoption Process

3.4 Conceptual Model Constructs

The conceptual model aims to evaluate the factors that influence the BIM adoption process within Nigerian SMAFs. In the context of this study, the factors that influence the BIM adoption process within Nigerian SMAFs are categorised within four categories (i.e. organisational, individual, environmental, and technology). Therefore, these categories form part of the conceptual model. In this regard, this section describes constructs within the conceptual model.

Table 3.2: Constructs of the BIM Conceptual Model

Category	Description
Organisational (Capability)	These are factors related to the firm's capabilities in terms of financial buoyancy, the availability of BIM to support the IT infrastructure, willingness to motivate, and innovative policies and processes to support BIM adoption.
Individual (Competence)	These are factors related to the individual's competency and perception of BIM adoption. These individuals are staff within the firm, such as the top manager, digital manager and employees. It also entails their ability to support, be self-motivated and accept innovation (such as BIM) without resisting.
Environmental (Control)	These are factors related to the environment (internal and external) which exert pressure and influence the behaviour of organisations and individuals to adopt BIM. These factors stem from internal pressure, such as work colleagues, or external pressure, such as business partners, clients request, and government or regulatory bodies.
Technological (Quality)	These are how the technology (such as BIM) can benefit and be suitable to the organisation. It also has to do with the perceived benefits (financial or otherwise) of the technology in providing the required output and the degree to which the technology is compatible with the existing workflow and processes.

From the established categories gathered from a literature review of BIM adoption within SMEs, a total of 11 clusters of factors were identified based on the four categories of the conceptual model, as shown in *Table.3, Table 3.4, Table 3.5,* and *Table 3.6*. These clusters form the constructs of the conceptual model. Thus, the subsequent section elaborates on these categories, components, and indicators.

3.4.1 Organisational capability

Organisational capability refers to the collective skills, abilities and expertise that drives meaningful business results (Ahuja et al., 2017). Therefore, several studies identify the need for organisations to develop their own BIM capability (S. Babatunde et al., 2018; Dainty et al., 2017; Ghaffarianhoseini et al., 2017; Hong et al., 2016). According to Succar et al. (2013), the competence of individuals is the building block of organisational capability. This is because the impact of the organisational capability performance cuts across different jobs throughout the firms. Similarly, the empirical study by Cao et al. (2017) on the motivations for BIM implementation in the construction industry identified and contextualised organisational capability among the primary motivational factors. This outcome shows a positive relationship between the organisational BIM capability and BIM implementation within the firms. However, the organisational capability related factors that have been identified from literature to influence BIM adoption within SMAFs are categorised into three main groups: management support, IT infrastructure, policy and process. Therefore,

Table.3 highlights the organisational capability related factors and their associated indicators, which are clustered under management support, IT infrastructure, process and policy.

Table.3: Criteria for The Organisational Capability Factors

Category	Construct	Reference	Criteria
Organisational Capability (Ahmed & Kassem, 2018) (Ahuja et al., 2020) (Qin et al., 2020)	Management Support	(Ahmed & Kassem, 2018; Ahuja et al., 2020; Cao et al., 2021; Doan et al., 2020; Kouch, 2018; Li et al., 2019; Manzoor, Othman, Gardezi, et al., 2021; Manzoor, Othman, Shujaa, et al., 2021; Murguia et al., 2021; Olanrewaju et al., 2020; Poirier et al., 2015; Walasek & Barszcz, 2017)	• Adequate investment funds to support innovation • Reward and incentive schemes for innovation • In-house training schemes for innovation • Strategic innovation management schemes • Research and development schemes
	IT Infrastructure	(Ahmed & Kassem, 2018; Cao et al., 2021; Kouch, 2018; Li et al., 2019; Manzoor, Othman, Gardezi, et al., 2021; Olanrewaju et al., 2020)	• Availability of digital hardware facilities • Availability of digital software facilities • Availability of network facilities • Availability of maintenance and upgrade facilities for technology
	Process & Policy	(Ahmed & Kassem, 2018; Ahuja et al., 2020; Cao et al., 2017, 2021; Kouch, 2018; Manzoor, Othman, Shujaa, et al., 2021; Murguia et al., 2021)	• Flexible administrative system for innovation • Flexible policy system for innovation • System for experimentation culture

Having contextualised the organisational capability, the subsequent section elaborates on the three components of organisational capability.

3.4.1.1 Management Support

Management support is among the top drivers of BIM adoption (Ahuja et al., 2020; Hatem et al., 2018). Management support is essential to provide the necessary resources (such as IT infrastructure, training, and an enabling environment) to develop individual competence and encourage BIM adoption (Wang & Song, 2017). However, providing the necessary resources, such as training, is costly (Hosseini et al., 2018); therefore, adequate funds need to be provided to ensure effective support.

Additionally, adequate financial funding is essential for management support to provide the necessary resources, such as training and schemes that motivate BIM adoption (i.e. reward and incentives) (Al-Hammadi & Tian, 2020). Howard et al. (2017) emphasised the importance of reward and incentive schemes in creating a competitive environment and increasing employees' performances when implementing BIM within an organisation. This is affirmed by several studies that identified the lack of incentive and reward schemes as barriers to BIM adoption (Hardin & McCool, 2015; Howard et al., 2017; Papadonikolaki, 2016; Piroozfar et al., 2019; Shepherd, 2019). Therefore, aligning financial incentives to the BIM-related process encourages employees during their firm's BIM adoption process (Papadonikolaki, 2016; Poirier et al., 2017).

Providing training to employees is an important preparatory stage to BIM adoption within a firm because training develops employees' competence (Casasayas et al., 2021; Kassem & Succar, 2017). Several studies have identified the lack of training support as a significant barrier to BIM adoption (Ahmed & Kassem, 2018; Chan et al., 2019; Herr & Fischer, 2019; Manzoor, Othman, Gardezi, et al., 2021; Martínez-Aires et al., 2018; Saka et al., 2020). However, according to Abdulfattah et al. (2017), in-house training schemes effectively develop individual competency and optimise BIM adoption within a firm. This enables employees to develop their theoretical understanding and practical application of BIM (Murguia et al., 2021). Additionally, Hamma-adama et al. (2018) suggested that training and retraining programs are a mechanism to increase BIM adoption within the Nigerian construction industry.

Manzoor et al. (2021) emphasised that firms can acquire better BIM value and greater competitive advantage by developing a strategic management scheme for BIM adoption. Hanafi et al. (2016) suggested that firms that have developed such schemes and shared strategies are more efficient at generating new ideas when managing innovation projects. This also applies to the BIM process (Succar et al., 2013; Succar & Kassem, 2015); indeed, Succar (2009) suggests firms take advantage of the benefits of using a strategy for BIM implementation, which enables them to sustain their competitive advantage by retaining knowledge resources. Therefore, strategic management schemes are guidelines that firms create to indicate to employees the necessary areas that need to be developed for BIM adoption. In addition, Ahmed & Kassem (2018) suggest that such a scheme provides a significant competitive advantage by creating and promoting the implementation of BIM ideas within a firm.

Overall, management support is among the most crucial factors to determine the success of BIM adoption within an organisation. As top management is responsible for the final decision to adopt BIM in an organisation, they are also responsible for providing adequate resources to support BIM adoption. These resources (such as training employees) might directly impact the individual competency needed to manage the BIM adoption process. Nonetheless, for management to effectively support the BIM adoption process, adequate finances must be available.

Additionally, adequate financial funds enable the firms to provide the schemes (such as financial incentives, research and development) necessary to support the organisation and motivate employees to adopt BIM effectively. Therefore, financial resource leads to BIM affordability for SMEs (Saka et al., 2020). Thus, from the above discussion, the management support related indicators established for this study are illustrated in *Figure 3.4*.

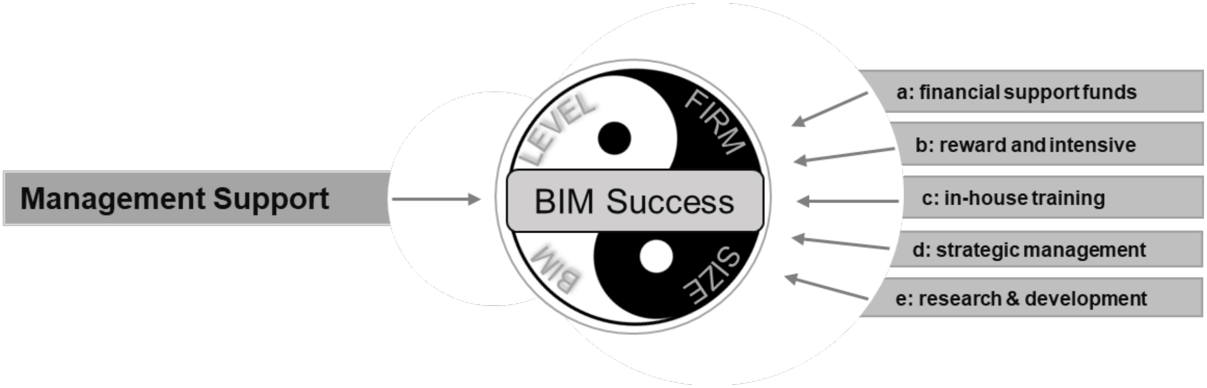


Figure 3.4: Management Support Component.

3.4.1.2 IT Infrastructure

IT infrastructure, such as software, hardware, network, upgrades and maintenance facilities, are the prerequisite components for BIM maturity in firms (Succar, (2009). Several studies demonstrated the influence of IT infrastructure in the BIM adoption process within firms (Ahmed & Kassem, 2018; Babatunde et al., 2021; Kouch et al., 2018; Manzoor, Othman, Gardezi, et al., 2021; Olanrewaju et al., 2020; Saka & Chan, 2019). The SMAFs particularly need to understand the requirement and impact of IT infrastructure due to their limited resources (Saka & Chan, 2021). Therefore, there is a strong relationship between the organisational capability in terms of IT infrastructure and the successful implementation of BIM. Haliburton (2016) suggested that, in information studies, the effectiveness of the firm's IT infrastructural facilities is particularly valued for improving innovation and knowledge sharing. Thus, from the above discussion, the IT infrastructure related indicators established for this study are illustrated in *Figure 3.5*.

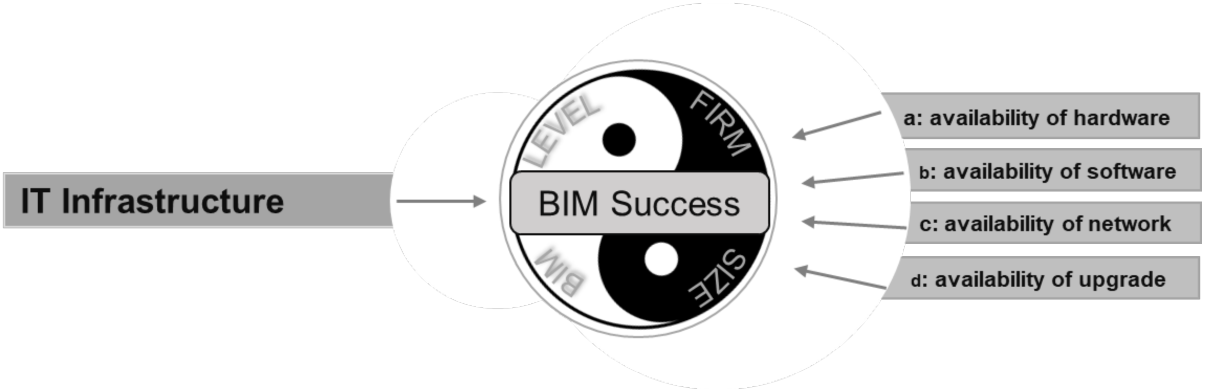


Figure 3.5: IT Infrastructure Component

3.4.1.3 Process and Policy

The importance of developing effective processes and policies to enhance the organisational capability needed for effective BIM adoption is well documented in the literature (Ahmed & Kassem, 2018; Cao et al., 2021; Kouch, 2018; Manzoor, Othman, Shujaa, et al., 2021; Murguia et al., 2021). Unlike other innovations, BIM is a multifaceted innovation (i.e. a product, process, and policy) that requires multiple stages of implementation to address distinct capability stages (i.e. modelling, collaboration, and integration (Ahmed & Kassem, 2018). Therefore, numerous countries are examining and developing national BIM policies to facilitate BIM adoption across their respective markets (Kassem & Succar, 2017). As a result, Nigerian SMAFs must adopt processes and rules consistent with their country's BIM policy. North et al. (2020) suggested that flexible administrative systems, policies, and experimental culture are needed to develop organisational capability when promoting digitisation in SMEs. These factors are also identified by Saka et al. (2020) as key to promoting BIM adoption within SMEs.

In SMAFs, the crucial element that defines successful innovation is an administrative system (Lu & Sexton, 2009). However, only certain types of administrative systems facilitate the creation and sharing of knowledge, which encourages learning (Gledson, 2016). In particular, Nonaka & Toyama (2015) noted that a flexible and informal management and administration system, associated with a hierarchical structure conducive to knowledge creation, was preferable to strict bureaucracy.

Furthermore, the benefits of an experimental culture when implementing BIM are highlighted in the literature (S. Babatunde, Udeaja, et al., 2020; Fadjar Maharika et al., 2020; Ghafar et al., 2018; Liao & Ai Lin Teo, 2018; Makarfi & Udeaja, 2019). However, Liu et al. (2019) suggest that knowledge sharing is crucial to facilitate an experimental culture within a firm, as this can challenge persistent patterns, and generate and test new ideas. Additionally, Qin et al. (2020) suggested that adopting an experimental culture system may improve the firm's cultural values such as building more trust, exploring new areas, learning from errors, greater transparency, open-mindedness, and cooperation, and mutual assistance to support experimentation. Therefore, a flexible policy system can be utilised to encourage an experimental culture within a firm (S. Babatunde, Udeaja, et al., 2020). Moreover, Succar (2009) and Succar & Kassem (2015) demonstrated the benefits of flexible, transparent and supportive policies and guidelines for the smooth implementation of BIM. Thus, from the above discussion, the policy and process-related indicators established for this study are illustrated in *Figure 3.6*.

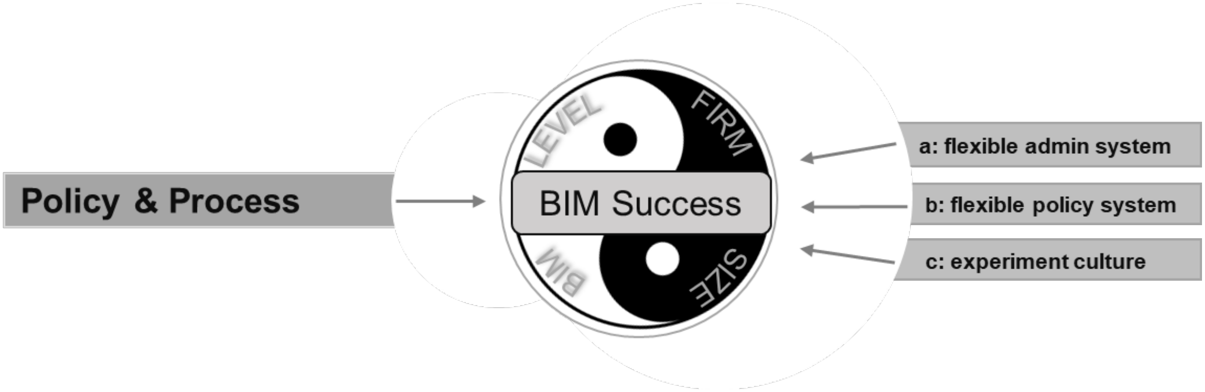


Figure 3.6: Policy and Process Component

3.4.2 Environmental Control

Environmental control refers to the degree to which factors related to the environment (internal and external) exert pressure on and influence the behaviour of organisations and individuals to adopt BIM. These factors stem from internal pressure from within the firm, such as work colleagues or superiors, or external pressure from outside the firm, such as business partners, client requests, and government or regulatory bodies (Hongping & Yu, 2020). According to O'Neill (2010), environmental control has numerous advantages, and an increasing amount of evidence suggests that the degree of environmental control, employees' performance, and organisational outcomes are strongly linked. However, the factors related to environmental control that influence BIM adoption within SMAFs, as identified in the literature, form categories under internal and external pressure. *Table 3.4* presents the related environmental control factors and their associated indicators clustered under internal and external pressure.

Table 3.4: Criteria for the Environmental Control Factors

Category	Construct	Reference	Criteria
Environmental Control (L. Ahmed & Kassem, 2018) (Ahuja et al., 2020) (Qin et al., 2020)	Internal Pressure	(Ahmed & Kassem, 2018; Makarfi & Kori, 2018; Manzoor, Othman, Shujaa, et al., 2021; Murguia et al., 2021)	• Pressure from work colleagues • Communication workflow • Participatory culture • To maintain image and reputation
	External Pressure	(Ahmed & Kassem, 2018; Doan et al., 2020; Kassem & Succar, 2017; Li et al., 2019; Manzoor, Othman, Gardezi, et al., 2021; Olanrewaju et al., 2020)	• The client knowledge and request • The technology marketplace in the innovative environment • The competitiveness in the innovative environment • The government and regulatory system • Business partners • Institutions of learning

Having contextualised the environmental control, the subsequent section elaborates on the three components of environmental control.

3.4.2.1 Internal Pressure

Internal pressure is defined as the organisational pressure exerted on an individual (i.e. pressure from compulsory policies, superiors, or colleagues) which influence their decision (Hong et al., 2019). Therefore, internal pressures result from interaction, communication, and collaboration between employees in the firm, which can be measured by sharing their knowledge and cultural experiences. In order to effectively adopt BIM, these internal pressures are required in a firm (Arayici, Coates, Koskela, Kagioglou, Usher, & O'reilly, 2011; Cao et al., 2014). Although this type of pressure may be informal when introducing BIM, it is a valuable resource for successful BIM adoption (Lee et al., 2015). Furthermore, Holzer (2015) highlighted that a potential resource during the BIM adoption process consists of the interaction between management, digital managers and employees. Additionally, Holzer (2015) emphasised that the internal setting of a firm provides an environment in which employees can remain flexible in an uncertain environment and enable a firm's social unit to respond meaningfully through competitive dynamic relationships among its members. Therefore, internal relationships foster competitive environment that are crucial to BIM adoption within firms.

Since the main objectives of the BIM process in enterprises are to improve and ensure effective communication and collaboration among project participants (Holzer, 2015), the importance of communication and its effects on the successful BIM adoption process cannot be over-emphasised. In addition, Tang et al. (2019) suggested that effective communication between employees has a strong positive relationship with increased job satisfaction, employee performance and ultimately positively influence BIM implementation.

The concept of participatory culture in firms has been identified as an essential factor to the implementation process of BIM, as it involves collaboration, evaluation and information sharing between different stakeholders inside and outside SMAFs (Arayici, Coates, Koskela, Kagioglou, Usher, & O'reilly, 2011; Cao et al., 2014). Therefore, teamwork is valued and the focus is more on collective work than on the individual, meaning that the firm and its employees share specific goals (Succar & Kassem, 2015). Participatory culture influences the firm's innovative values and requires input from employees and other stakeholders to ensure the accurate analysis of their decisions and policies (Azam, 2015). Zhao et al. (2015) also demonstrated the value of participatory culture when gathering feedback and information from internal relationships, which acts as an open system for the capture of employees' opinions and concerns. This enables an adequate flow of information and provides a collaborative environment that allows employees and lower-level staff to participate in management decisions. As a result, employees are encouraged to accept decisions relating to BIM adoption within the firm since they were involved in the decision process, thus giving them a sense of value. From the above discussion, the internal pressure related indicators established for this study are illustrated in *Figure 3.7*.

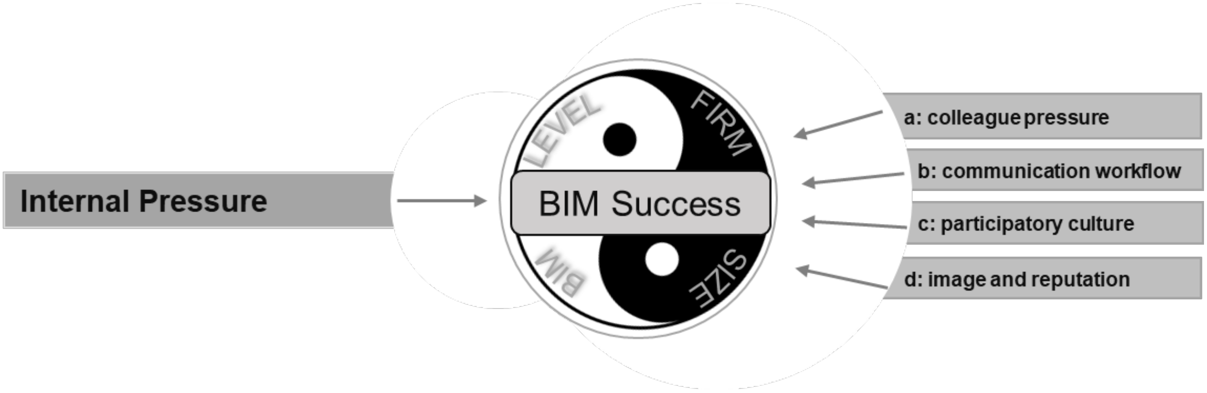


Figure 3.7: Internal Pressure Component

3.4.2.2 External Pressure

External pressure is defined as the pressure from outside the organisation exerted on an individual and organisation (i.e. pressure from the client, government, regulatory bodies or business partners) which influence their decisions (Hong et al., 2019). Several studies identified external pressure-related drivers of BIM adoption as learning institutions (Ahmed & Kassem, 2018), government and regulatory bodies (Belay et al., 2021), pressure from client requests (Eadie et al., 2015), pressure from business partners (Jerónimo et al., 2016), and pressure from the competitive market place (Ahuja et al., 2018; Murguia et al., 2021).

Mohammad et al. (2019) describe the competitive market environment as a place where firms compete with other firms for clients and other scarce resources. Therefore, firms are pressured to gain a competitive advantage through adopting BIM. Kassem & Succar (2017) study found that the construction industry diffusion dynamic exhibited a middle-out approach where large contractors started BIM adoption and exerted pressure on other supply chain members (e.g. architects, engineers, and clients) to use BIM. Similarly, Juan et al. (2017) affirmed that pressure from their competitors would increase the motivation and readiness to implement BIM amongst architectural firms. Moreover, another study by Belay et al. (2021) conducted an empirical investigation that compared the BIM adoption model between the public and private sectors. The outcome emphasised that the BIM adoption drivers in common to both sectors, such as customer pressure, competitive pressure, and government pressure, affected BIM adoption's intention and decision stages.

The idea of regulatory bodies driving innovation was developed in the literature (Wang & Lu, 2021). Although this is evident in the case of the United Kingdom, where regulations are facilitators of the widespread acceptance of BIM in the industry (Succar & Kassem, 2015), a study on BIM acceptance in South Korea (Lee & Yu, 2017) indicates that regulatory pressures may negatively affect the industry's willingness to accept BIM. Furthermore, Toole (1998) suggested that regulations, such as building codes, contributed to the conservativeness of the building industry in the 1990s. However, this assertion can now be challenged following the change in the regulatory position, as seen in the UK's 2019 published standards. As such, it makes sense to consider regulatory bodies as a potential indicator of BIM innovation in SMAFs. Thus, from the above discussion, the external pressure-related indicators established for this study are illustrated in *Figure 3.8*.

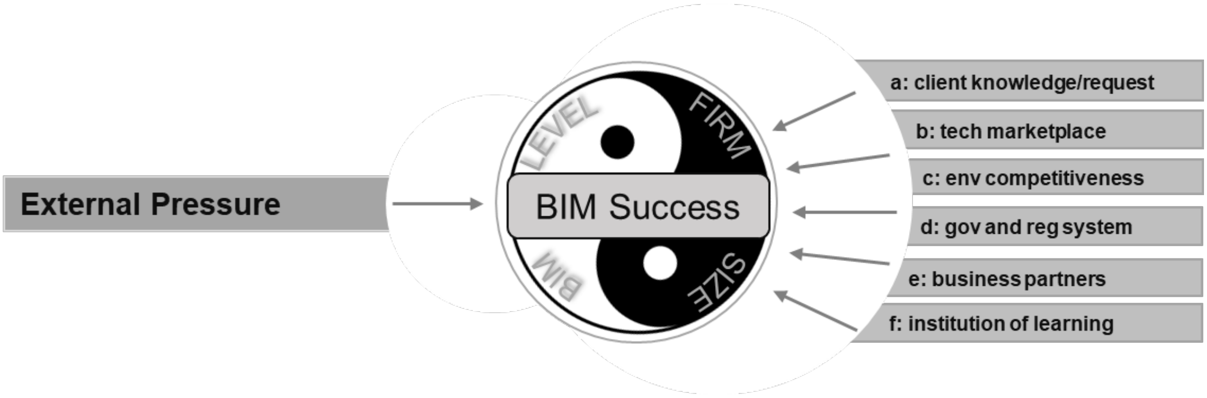


Figure 3.8: External Pressure Component

3.4.3 Individual competence

Individual competencies are described as “the personal traits, professional knowledge and technical abilities required by an individual to perform a BIM activity or deliver a BIM-related outcome. These abilities, activities or outcomes must be measurable against performance standards and can be acquired or improved through education, training and/or development.” (Succar et al., 2013, p178). Among construction professionals, individual competence has been viewed as one of the baseline indicators of a firm’s BIM readiness (Adam et al., 2021). Therefore, individual competence is among the building blocks of organisational capability (Manu et al., 2019). The individuals identified from the literature as influencing the success of BIM adoption within SMAFs are the top manager, digital manager, and employee (Holzer, 2016). Therefore, *Table 3.5* highlights the individual competency related factors and their associated indicators, which are clustered under the top manager, digital manager and employee.

Table 3.5: Criteria for The Individual Competence Factors

Category	Construct	Reference	Criteria
Individual Competency	Top Manager	(Ahmed & Kassem, 2018) (Murguia et al., 2021) (Angelo et al., 2018) (Manzoor, Othman, Gardezi, et al., 2021)	• The ability to inspire others • Strategic knowledge of innovation • The quality of teamwork
	Digital Manager	(Ahmed & Kassem, 2018) (Ahuja et al., 2020)(Walasek & Barszcz, 2017) (Doan et al., 2020) (Angelo et al., 2018) (Manzoor, Othman, Gardezi, et al., 2021)	• The digital manager is on a permanent basis • The digital manager has a higher education qualification • The digital manager has previous IT experience. • The digital manager has higher Job Satisfaction
	Employee	(P. Li et al., 2019) (Ahmed & Kassem, 2018)(E. Poirier et al., 2015)(Cao et al., 2021) (Angelo et al., 2018) (Manzoor, Othman, Gardezi, et al., 2021) (Kouch, 2018)	• Employees with regular training • Employees with a willingness to accept innovation • Employees with self-motivations • Employees with innovative shared value

Having contextualised individual competence, the subsequent section elaborates on the three components of individual competence.

3.4.3.1 Top manager

The top manager’s ability to plan strategically and willingness to accept change are integral elements of BIM adoption within a firm (Ahmed & Kassem, 2018). Therefore, the top manager’s strategic knowledge should be complemented by the desire and ability to change in order for BIM adoption to be successful within SMAFs. Also, Mohd

Sabri et al. (2018) identified the lack of management support and top managers' reluctance to take risks due to the uncertainty of change as barriers to developing individual competence in firms. These two criteria indicate the need for empirical evidence of their impact on the BIM adoption process. Wang & Song (2017) also suggested that top managers should develop and manage individual competence to support BIM adoption. Although the qualities of top managers in most studies were considered to be proper planning and administrative routines, Succar et al. (2013) highlighted the qualities of teamwork and the ability to inspire others as integral elements of the overall competence and performance required for firms to adopt BIM. Therefore, the ability of the top manager to effectively collaborate, communicate and inspire colleagues, employees, or team members contribute toward BIM adoption within the firm.

Additionally, according to the regulations of most countries, professionals such as architects often have all the necessary educational and professional experience. Oluwatayo & Amole (2013) reaffirmed that there was no correlation between the educational level of top managers and an architectural firm's performance. Therefore, despite the importance and impact of educational and professional qualifications on the firm's performance and innovation, neither can be used as an indicator to understand the difference between the way users of BIM adopters and non-adopters differ in their individual competence within SMAFs. Additionally, the educational level of top managers in architectural firms did not necessarily affect the firm's ability to innovate, as it was a fundamental criterion their role in the profession. Thus, from the above discussion, the top manager related indicators established for this study are illustrated in *Figure 3.9*.

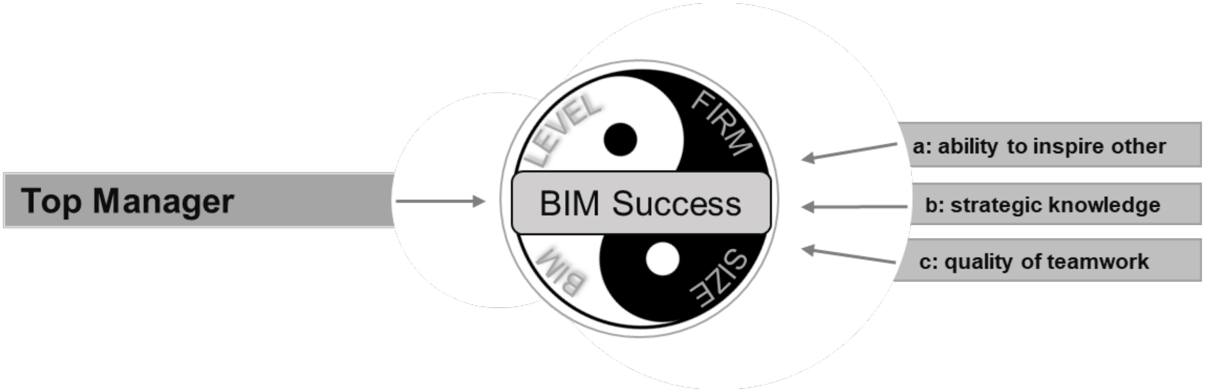


Figure 3.9: Top Manager Component

3.4.3.2 Digital manager

Digital managers play an essential role as facilitators of change in the process of adopting BIM, and their competence and performance can be essential for BIM adoption in SMAFs (Holzer, 2015; Hong et al., 2018; Tulke & Schumann, 2018). Hence, as facilitators of change, digital managers support and encourage employees to overcome their fear factor through advocating the benefits and change process needed to adopt BIM (Arunkumar et al., 2018). Holzer (2016) emphasised the importance of the digital manager in promoting BIM adoption and suggested that they should build a keen awareness of the situations they face in their organisations. Their understanding of the broader context of the industry when it comes to adopting technology and aligning it with current practices allows digital managers to cope with the changing context that affects their professional and personal lives (Jacobsson & Merschbrock, 2018). Therefore, the digital manager in this context can be defined as the staff responsible for championing technological innovation of the firm, such as BIM (Maskil-Leitan & Reychav, 2018). This can be the BIM manager for the BIM adopters, while for non-adopters, it can be anyone responsible for managing and championing the firm's digital activities (Ahmed & Kassem, 2018). Bui et al. (2016) and Merschbrock & Munkvold (2015) suggested that employing BIM managers in construction projects might be more successful when implementing BIM. Angelo et al. (2018) argued that hiring a BIM champion is crucial for employees to gain more confidence. Therefore, a BIM manager's competencies comprise experience in the design and construction planning process, specific IT knowledge and practical software application skills, and the contextual knowledge of international BIM guidelines and standards (Tulke & Schumann, 2018). Additionally, the outcome of the study by Rahman et al. (2016) on the skillset needed for project managers and BIM managers when implementing BIM affirmed that digital managers require adequate educational qualifications, IT experience, and a practical and technical skillset to implement BIM effectively.

Overall, the digital manager is crucial in the successful adoption of BIM within a firm. The role of a digital manager can be assumed by an individual responsible for championing the adoption process within the firm, such as a BIM manager. The digital manager should have greater job satisfaction as it affects their performance. Greater job satisfaction could be a result of the nature of the digital manager's employment. However, to champion BIM activities effectively IT experience is important to support the employees and other stakeholders involved in the adoption process. This can be complemented with a thorough understanding of the contextual knowledge of BIM guidelines and standards. Thus, educational qualification tends to be a requisite for the position of digital manager. In this regard, considering the above discussion, the digital manager related indicators established for this study are illustrated in *Figure 3.10*.

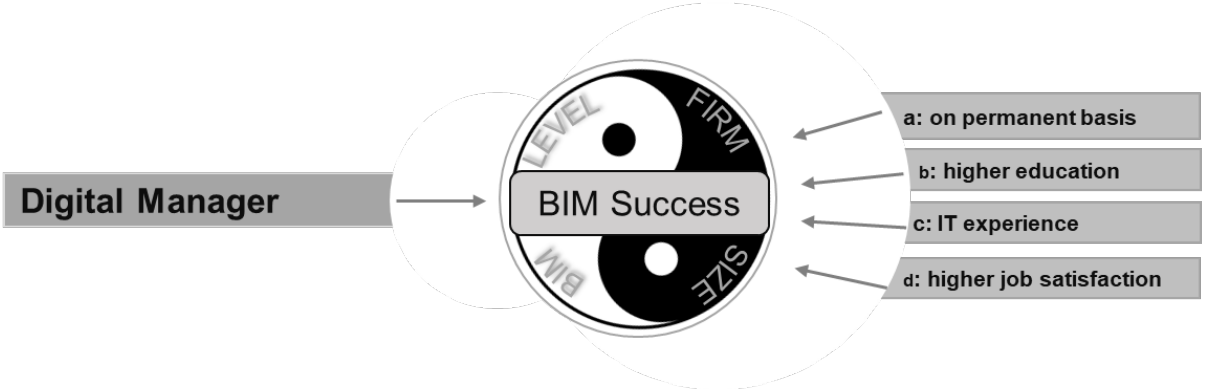


Figure 3.10: Digital Manager Component

3.4.3.3 Employees

Employees in this context are staff or individuals within SMAFs who do not occupy a top managerial position and whose activities are required to achieve the firm's tasks. Oyewole & Dada (2019) argued that a firm's staff or employee is the sole resource that cannot be replicated. Thus, it is the primary source of a firm's competitive advantage. Therefore, gaining the support of top management and lower-level employees is crucial when adopting BIM (Angelo et al., 2018). Similarly, a study on systematic BIM adoption from a multilevel perspective suggested that, to promote user adoption, support and resources should be given to BIM teams and, more fundamentally, to the rest of the employees (Murguia et al., 2021). Manzoor, Othman, Shujaa, et al. (2021) research framework for mitigating BIM implementation barriers ranked the individual related barriers as a lack of vision of the benefits, a lack of BIM training, and cultural barriers (i.e. resistance to change), respectively. This suggests that, to effectively adopt BIM within the firms, employees need to have a vision of its benefits, attend regular training, and be willing to accept change.

Additionally, understanding the firm's vision enables employees to align their beliefs and values with the firm. These shared beliefs and values encourage employees to adopt BIM (Batarseh & Kamardeen, 2017). Additionally, McGuirk et al. (2015) suggested that employee competence and openness to accept innovation, such as BIM, are found to be related to their individual cognitive and intellectual abilities. However, for employees to gain the competence needed for BIM adoption, top management is crucial to their training and upskilling within SMAFs. This is logical because top management usually comprise the sole proprietor of a small business whose decision is final (Saka et al., 2020).

Additionally, Ahuja et al. (2018, 2020) pointed out that employees are among the factors that influence BIM adoption in emerging markets. The characteristics of the highlighted employees are the ability to motivate themselves and the possession of shared beliefs or values with the firm's goals. This confirms the assertion of McGuirk et al. (2015) on the importance and impact of employees' self-motivation, competence, beliefs, and values when it comes to adopting innovation.

Overall, employees are crucial to the effective adoption of BIM. Therefore, employee competence needs to be nurtured and aligned to the firm's requirement for the successful adoption of BIM. Nonetheless, other factors, such as top management's support for training and incentive schemes, influence the development of employee competence. These factors are identified as barriers to BIM adoption within Nigerian SMAFs (Al-Hammadi & Tian, 2020; Amuda-Yusuf, 2018; S. Babatunde, Udeaja, et al., 2020). Above all, the identified factors related to the employee competence required for the effective adoption of BIM, including regular training, a willingness to accept BIM, having a shared belief (and values) or a BIM vision for their firm, and being self-motivated. Thus, from the above discussion, the employee-related indicators established for this study are illustrated in *Figure 3.11.*

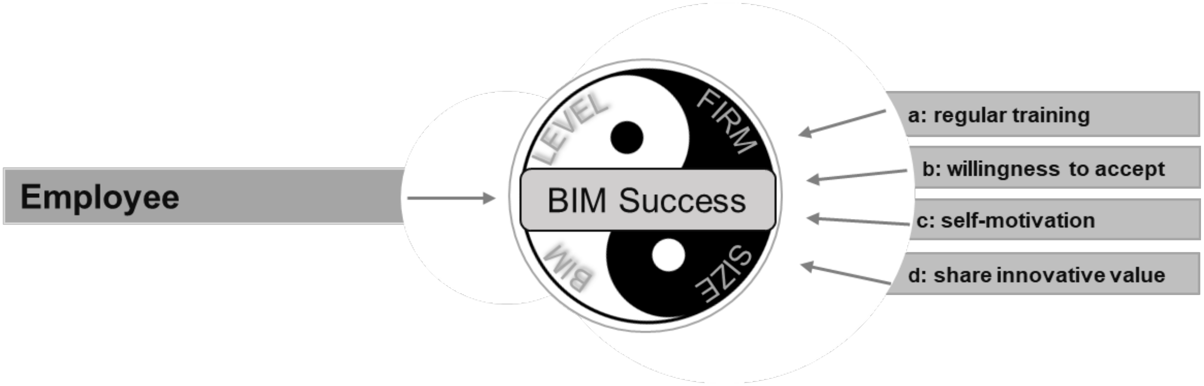


Figure 3.11: Employee Component

3.4.4 Technological Quality

The technological quality comprises key factors related to the performance of BIM tools (Hong et al., 2019). Quality-related factors regarding technology, such as perceived usefulness and ease of use (Davis, 1989), and its relative advantage, complexity and compatibility (Rogers, 2003) are key considerations for firms when determining the value of innovations, such as BIM (Hochscheid & Halin, 2020). Previous literature identified three main clusters of technological related factors for BIM adoption: the relative advantage, complexity, and compatibility of BIM tools.

Table 3.6 shows the nine criteria used as measurement items (indicators) when evaluating these technological quality constructs.

Table 3.6: Criteria for The Technological Quality Factors

Category	Construct	Reference	Criteria
Technological Quality (Ahmed & Kassem, 2018) (Ahuja et al., 2020) (Qin et al., 2020)	Compatibility	(Ahmed & Kassem, 2018; Ahuja et al., 2020; Doan et al., 2020; Li et al., 2019; Manzoor, Othman, Gardezi, et al., 2021; Murguia et al., 2021; Walasek & Barszcz, 2017)	• It is compatible with our current work process and software • It is compatible with our beliefs and values • It provides us with the desired outcome
	Complexity	(Ahmed & Kassem, 2018; Ahuja et al., 2020; Li et al., 2019; Murguia et al., 2021)	• It is easily applicable to our workflow • It is simpler and reliable to access data, information and knowledge • It is easy to use
	Relative Advantage	(Ahmed & Kassem, 2018; Ahuja et al., 2020; Cao et al., 2021; Manzoor, Othman, Gardezi, et al., 2021; Walasek & Barszcz, 2017)	• It gives our firm a competitive advantage • There are tangible, measurable benefits • It saves us time in the design and delivery of projects

Having contextualised the significance of technological quality, the subsequent section elaborates on its three components.

3.4.4.1 Compatibility

BIM requires the effective integration of multiple software applications, and only a common data exchange standard enables successful data transmission (Hosseini et al., 2015). Rogers' (2003) diffusion of innovations model defined compatibility as the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters. Compatibility relates to the fit between any new technology and the individual's existing experiences and job responsibilities (Kuo & Lee, 2011). Therefore, if the technology is compatible with the firm's current work practices, the adoption of BIM will increase (Son et al., 2015). Considering that the effective implementation of BIM needs collaboration and data integration through compatible technology, negative attitudes towards data sharing hinder the ultimate success of BIM implementation (Zhang et al., 2018). This is supported by a previous BIM-related study that recognised compatibility as an essential predictor of BIM acceptance/adoption (Son et al., 2015). As such, Papadonikolak (2018) argued that the compatibility of BIM with existing values influences the rate at which innovation spreads either rapidly or slowly.

According to TAM, adoption behaviour is determined by the intention to use a system or technology, which, in turn, is determined by the perceived usefulness and perceived ease of use of that system or technology. Based on the assumption that an individual's cognitive beliefs, perceived usefulness, and perceived ease of use influence system usage, Son et al. (2015) extended TAM by adding variables, such as top management support, subjective norm, compatibility, facilitating conditions, and computer self-efficacy. The study's conclusion suggested that compatibility will increase BIM usefulness and the system's ease of use. Additionally, studies such as Tan, Chen, Xue, & Lu (2019) aimed to identify the factors that influence BIM adoption decisions in small and medium organisations (SMOs). The outcome shows that three main factors - awareness, ease of use, and innovativeness - are critical factors influencing an organisation's decision to adopt or reject BIM. However, the study indicates that complexity and compatibility are the main specific barriers to BIM implementation.

The above discussion identified compatibility as a significant factor influencing firms' BIM adoption, especially within SME's. In addition, compatibility, as identified in the DOI, affects the perceived ease of use and usefulness of technology, which are vital constructs of TAM. Hence, while developing a conceptual model of this research by identifying the key factors that influence BIM adoption, there is a need to consider the technology's compatibility as a determinant of BIM adoption within the context of this study. Thus, from the above discussion, the compatibility related indicators established for this study are illustrated in *Figure 3.12*.

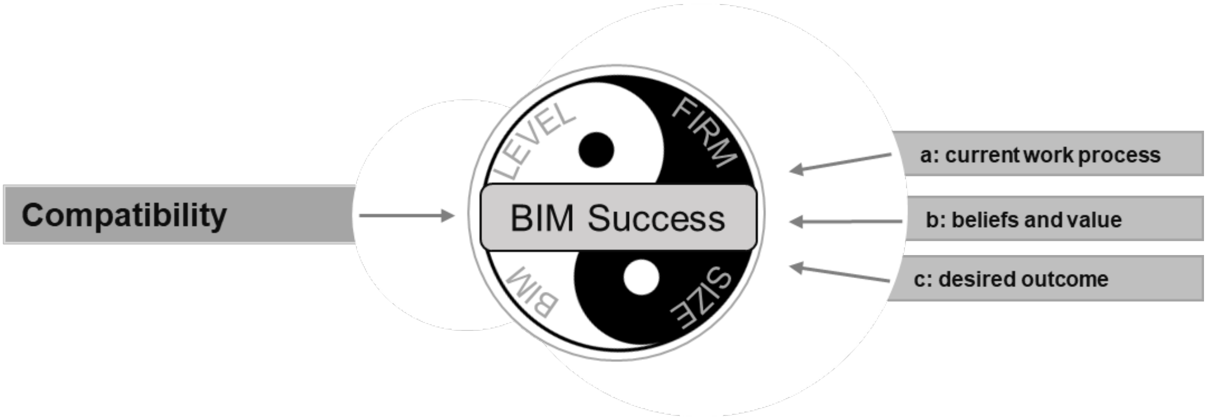


Figure 3.12: Compatibility Component

3.4.4.2 Complexity

The previous section identified compatibility and complexity as significant factors that affect BIM adoption (Tan et al., 2019). However, complexity has been defined as whether firms perceive an innovation challenging to use or adapt (Rogers, 2003).

Prior research has found that complexity negatively influences BIM adoption (Tan et al., 2019). Compared to larger organisations, SMEs have limited resources to address issues that increase the costs (Azmi et al., 2016). Therefore, SMEs may struggle with handling the system and integrating it into their business processes and organisational culture. Thus, the complexity of new technology will discourage and reduce its usage (Ahani et al., 2017).

The perceived ease of use (PEOU) is similar to the complexity of the perceived characteristics of Rogers' diffusion theory of innovations, although in the opposite direction (Venkatesh et al., 2003). Prior studies have identified similarities between complexity in DOI, perceived ease of use in TAM and effort expectancy in UTAUT as a significant predictor of adoption behaviour (Arpaci, 2013; van Oorschot et al., 2018). In addition, Mohammad et al. (2018) found that the complexity construct has a strongly significant effect on BIM adoption because the complexity of these technologies largely depend on how easy it is to perform these tasks. In the context of BIM, complexity is the degree to which firms perceive the use of BIM technology as complicated. Complexity is related to the effort a firm makes to learn and use new technology. The easier a firm perceives a new technology, the less complex it is perceived to use, and vice versa. The concept of complexity is another crucial technological factor that must not be ignored in technology and BIM adoption. Using BIM technology to manage complex project information is among the significant advantages of BIM technology. Although BIM usage enables greater access to project information and faster communication with project stakeholders, it would be interesting to identify how the complexity of BIM, as an example of a new IT-based strategy, as this can be critical in SMEs' adoption decisions. Hence from the above theoretical and empirical support, this research considers the complexity of BIM technology as a determinant of BIM adoption by Nigerian SMAFs. Thus, from the above discussion, the related complexity indicators established for this study are illustrated in *Figure 3.13*.

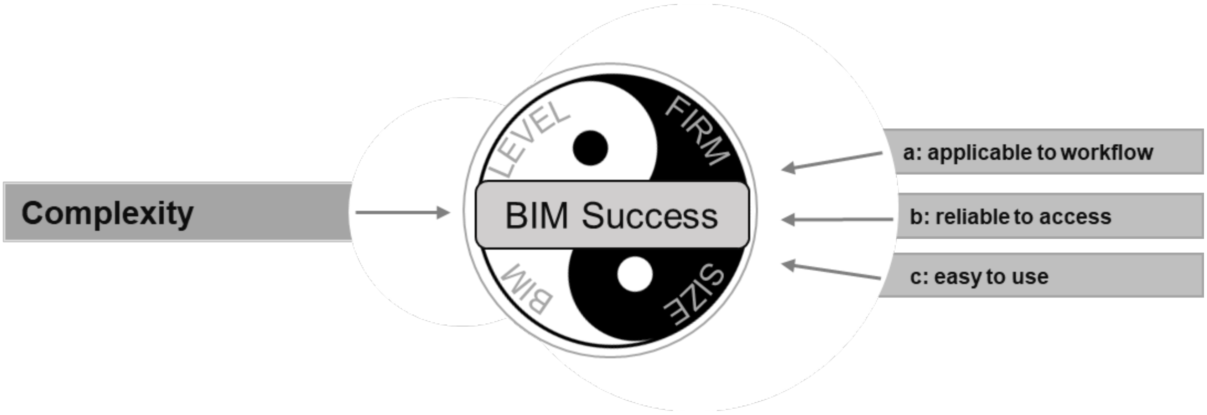


Figure 3.13: Complexity Component

3.4.4.3 Relative Advantage

Relative advantage is the degree to which an innovation is perceived as better than the idea it supersedes (Rogers, 2003). The degree of relative advantage is often expressed in economic profitability, but the relative advantage category may be measured in other ways (Napaporn & Arthur, 2009). The study by Addy et al. (2018) on BIM adoption among surveyors in Ghana provided empirical evidence of the factors that facilitate BIM adoption. After concluding the investigation, performance expectancy was identified as the primary factor to facilitate BIM adoption. However, the two significant determinants of performance expectancy are relative advantage and outcome expectations. Therefore, a firm's belief that using BIM will provide a relative advantage (as a construct of performance expectancy) will enhance job performance. In addition, Venkatesh et al. (2003) describe performance expectancy (determined by the relative advantage construct) as the first construct of the UTAUT2 model, defined as the level to which individuals assert that using technology will improve their job performance. Similarly, Hatem et al. (2018) explored the barriers to BIM adoption in Iraqi construction projects. Poor knowledge about the benefits of BIM was among the significant barriers to BIM adoption. Several studies have affirmed this to be the case for SMEs (Ayinla & Adamu, 2018; Monozam et al., 2016; Poirier et al., 2017; Saka & Chan, 2021). Therefore, understanding the tangible, measurable benefits of adopting BIM will encourage individuals, organisations, and governments to facilitate BIM adoption.

Overall, examining the factors that influence BIM adoption among SMAFs, as the level of understanding of the relative advantage of BIM is higher, the greater the chances that the firm successfully adopts BIM (Saka & Chan, 2020). A firm's relative advantage when BIM is adopted includes a competitive edge, tangible, measurable benefits, and advantages when delivering a project. Hence, from the discussion above, relative advantage-related indicators established for this study are illustrated in *Figure 3.14*.

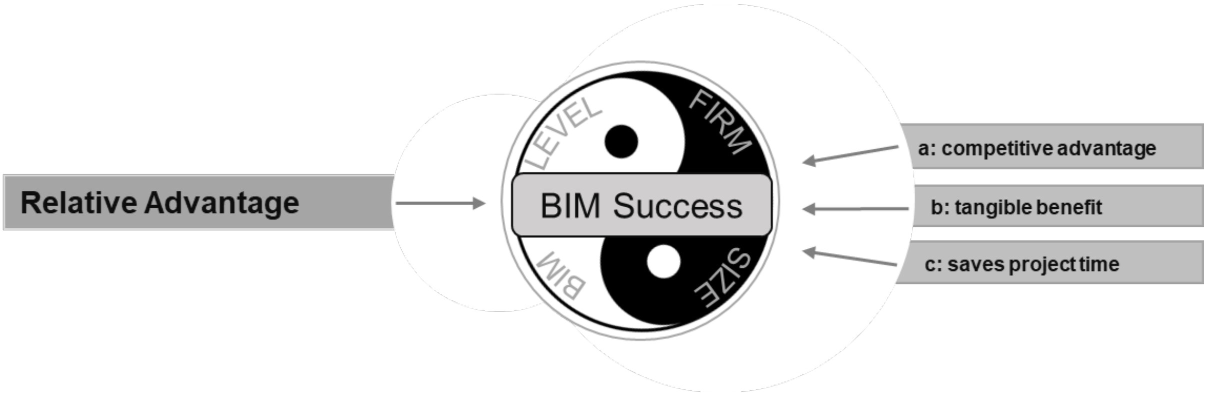


Figure 3.14: Relative Advantage Component

3.5 Conceptual Model

Based on discussions on the developmental aspects of the conceptual model (i.e. categories, constructs, and criteria), the study developed a comprehensive evaluation model, as presented in *Figure 3.15*, based on a comprehensive review of the extant literature. Thus, the conceptual model consists of four categories and a total of 11 associated constructs, namely organisational capability (management support, IT infrastructure, process and policy), individual competence (top manager, digital manager, employee), environmental control (internal pressure and external pressure), and technology quality (relative advantage, complexity, and compatibility). However, in adopting system approach theory, the conceptual model integrates four interrelated parts (organisational capability, individual competence, environmental control, and technology quality). These parts provide a conceptual explanation of the empirical study areas of this research. Figure 3.15 shows a graphical representation of the constructs developed for the empirical enquiry stage of this research. The conceptual model constructs will be evaluated and validated in the subsequent chapter through a quantitative study. Furthermore, the validated conceptual model will be evolved to form the final framework.

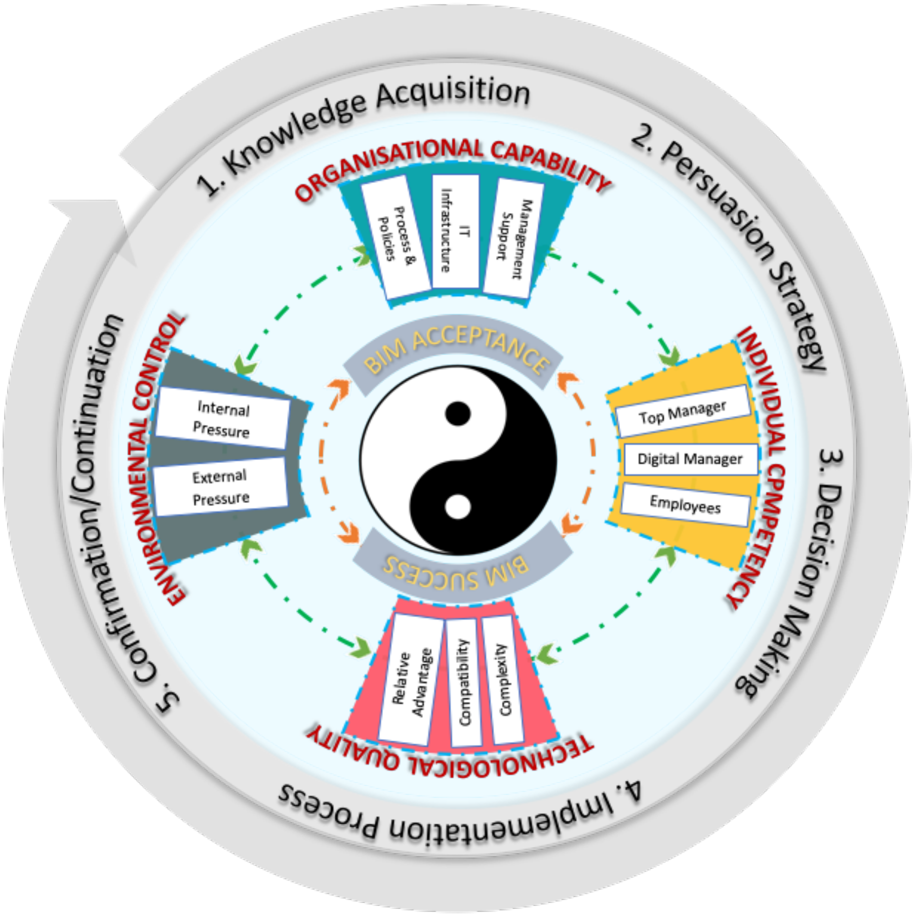


Figure 3.15: Research Conceptual Model Diagram

3.6 Chapter Summary

The chapter provided an overview of the reviewed BIM-related theories used in previous literature to develop BIM models or frameworks. The theories reviewed identified four categories and 11 associated components (constructs) as factors that influence BIM adoption within Nigerian SMAFs. The first category, organisational capability, includes the firm’s capability to provide adequate management support, IT infrastructure facilities, and appropriate process & policies. The second category, individual competence, consists of three components, namely the competence of the top manager, digital manager, and employees. The third category, environmental control, consists of two components: the firm’s ability to control the environment through internal and external pressure. The fourth category, technological quality, consists of three components: the quality of the firm’s technology based on its compatibility, complexity, and relative advantage. The outcome of the conceptual model development highlighted 42 key factors that have the potential to influence the BIM adoption process within Nigerian SMAFs. Overall, the conceptual model will facilitate the evaluation of the various constructs (categories, components, key factors) that influence BIM adoption within Nigerian SMAFs. Thus, these evaluated constructs will provide empirical evidence of the extent to which they influence BIM adoption in the quantitative chapter. Nonetheless, the next chapter presents the philosophical and methodological underpinnings of the empirical research enquiry.

4 Chapter Four – Methodology

4.1 Chapter Overview

Subsequent to developing the conceptual model, this chapter identifies the most appropriate methodological strategies for the study by reviewing existing research strategies. The three most important questions answered in this chapter are: (i) what are the philosophical positions of the research; (ii) what are the adopted research methodologies; and (iii) how are the chosen methods to be used in this study? These three essential issues will be logically and rationally addressed within this chapter, which presents a discussion and justification for the research choices adopted, including the research strategy, design and ethical considerations. In light of the above, the next section presents the research methodological design models.

4.2 Research Classification

Research is defined as "the systemic and rigorous process of enquiry which aims to describe phenomena and to develop and test explanatory concepts and theories, in order to contribute to a scientific body of knowledge" (Bowling, 2009, p. 16). Therefore, a researcher is expected to select a specific type of research before commencing a study. In light of this, Saunders et al. (2019) argued that an understanding of the type of research should be based on the justified purpose and supported by an appropriate process and logic. Thus, Saunders et al. (2019) classified the types of research based on the purpose, process, and logic, as shown in *Table 4.1.*

Table 4.1: Research classifications and types

Adapted from Saunders et al. (2019)

Type of Research	Classification
Exploratory, Descriptive, and Explanatory	Purpose
Quantitative, Qualitative, and Mixed	Process
Deductive, Inductive, and Abductive	Logic

In *Table 4.1,* exploratory, descriptive, and explanatory are listed as the three basic forms of research, which accord with the views of Saunders et al. (2019). The purpose and objectives of the study are typically used to determine the type of research to be conducted. Therefore, this step is important because it allows the researcher to gain a better understanding of the structure of the methodology and the assumptions that underpin the study. As such, the discussion and justification of the purpose is presented in the subsequent section, while the process and logic is presented further in this chapter (see section *4.5*).

4.2.1 Exploratory Research

Exploratory research is defined as a useful method for discovering and gaining in-depth knowledge about a topic of interest; it is frequently accomplished by asking open questions (Saunders et al., 2019). Interviewing 'experts' in the field, conducting a critical literature review, and holding focus group interviews can all be used when undertaking this type of study. Participants tend to be chosen based on the quality and quantity of information they are expected to provide. Furthermore, this form of research can help to clarify and offer an in-depth comprehension of an existing scenario, allowing for the identification of issues and the creation of avenues for more precise future inquiry. According to Collis and Hussey (2003), exploratory research is likely to be employed for qualitative measurements. Furthermore, it is also used to produce theories from the examination of a situation or to uncover and analyse hypotheses, concepts and patterns. Exploratory research has the advantage of being flexible and adaptable to change.

4.2.2 Descriptive Research

In contrast, descriptive research, according to Chapman and McNeil (2005), aims to answer inquiries about what, who, and how many; it describes a situation or set of circumstances in details. This form of study yields a precise depiction of people, events or circumstances, while its goal is to provide information on the status of a wide variety of social indicators and to raise concerns that may lead to the need to elucidate why such a phenomenon exists (Saunders et al., 2019). In descriptive research, statistical or quantitative techniques can also be employed to collect and analyse data. This implies that descriptive research aims to provide an overview of a phenomenon's characteristics rather than the reasons for its existence (De Vaus, 2001). However, the conduct of exploratory and explanatory types of research can be facilitated through descriptive research.

4.2.3 Explanatory Research

Finally, according to Collis and Hussy (2003), explanatory research can use both qualitative and quantitative methodologies to examine and explain why and how a phenomenon occurs or has occurred. According to Saunders et al. (2019), explanatory research explains a situation by identifying causal relationships between variables when examining a phenomenon. Explanatory studies are difficult to distinguish from descriptive research because both strive to answer "why" questions, and every explanation involves description. Nevertheless, according to DeVaus (2001), an explanation is utilised to determine why a phenomenon exists in order to propose solutions, whereas a description just provides an overview of the phenomenon. In reality, explanatory research is used to explain how variables in a scenario or problem interact or relate to one another.

4.2.4 Adopted Type of Research Justification

The aim of this research is to ultimately develop a framework to understand BIM adoption within Nigerian SMAFs. However, to achieve this, there is a need to identify the factors that influence BIM adoption and to understand their relationships. Considering this, the opinions and perceptions of experts - based on their experience - is crucial when understanding the situation amongst Nigerian SMAFs.

Therefore, from the three types of research discussed previously (see sections 4.2.1, 4.2.2, and 4.2.3), explanatory research is deemed as capable of explaining the reasons why and how this phenomenon occurs/occurred within this particular context (i.e. the reasons and processes of BIM adoption within Nigerian SMAFs). This contrasts with descriptive research, which is limited to only providing a general overview of a phenomenon (i.e. BIM adoption). Additionally, Saunders et al. (2019) affirmed that explanatory research is used to explain a situation by identifying "relationships between variables" when examining a phenomenon, which is exactly what this research intends to achieve (i.e. to explain the relationship between the factors that influence BIM adoption within SMAFs). Therefore, explanatory research is adopted as it is considered the most appropriate based on the main objective of this study, which intends to understand BIM adoption process within Nigerian SMAFS by establishing relationships between the factors that influence BIM adoption and the adoption process. In this regard, the subsequent sections present the research methodology design models and philosophical stance.

4.3 Research Methodology Design Models

Research can be described as knowledge retrieval (Saunders et al., 2019). Unlike other fields of knowledge, research follows a systematic process of collecting, analysing and presenting data for future use (Mertens, 2009). This process generally aligns with the purpose, aims and objectives of the research (Marshall and Rossman, 1999). According to Blessing and Chakrabarti (2009), research design can be defined as a systematic approach that complies with a set of supporting techniques and guidelines that should serve as a model for carrying out a study. As noted by Blessing and Chakrabarti (2009), a model helps researchers identify their areas of study and find ideal ways to address the issues raised. However, Crotty (1998) highlighted that identifying philosophical perspectives on research design can support the development of a comprehensive research strategy.

According to Crotty (1998), there is a close connection between the position of the researcher or the epistemological assumptions, theoretical perspectives, methodological philosophy and methods adopted. Crotty (1998) argues that a problem with research models is their vague set of theoretical perspectives and methods and the fact that the terms applied to them are often inconsistent or even contradictory. *Figure 4.1* shows the main components of the study and their relationships.

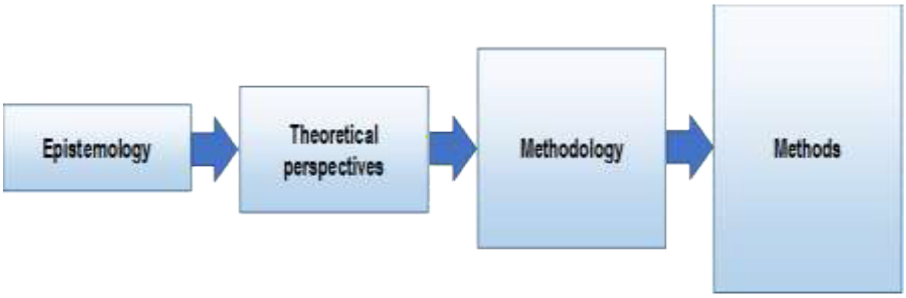


Figure 4.1: Methodological Research Components Relationship (Crotty, 1998)

According to Crotty (1998), the selection of methods closely relates to the research methodology decisions, which consider how to generate the data required for a particular study. Similarly, methodological interventions tend to produce a theoretical perspective that has been assumed and are themselves influenced by the epistemological assumptions of the researcher. However, as shown in Figure 4.2, the 'Nested Research Methodology Model', developed by Kagioglou et al. (1998), stipulates that philosophical research is part of a series of three different perspectives that comprise philosophies, approaches, and techniques.

Figure 4.2: Nested Research Methodology Model (Kagioglou et al. 1998)

The nested model offers an easy way to reflect the main components of systematic research by distinguishing the main classifications and focusing on the research methods and techniques. However, the ‘Research Onion Model’ developed by Saunders et al. (2016) is more comprehensive by encompassing six levels, namely philosophy, approach, methodological choices, strategies (lens), time horizons, and procedures. Furthermore, as shown in *Figure 4.3*, Saunders et al. (2016) reflect all components, starting with the research philosophy at the outer layer moving through to the research techniques to collect and analyse data at the inner core of the model.

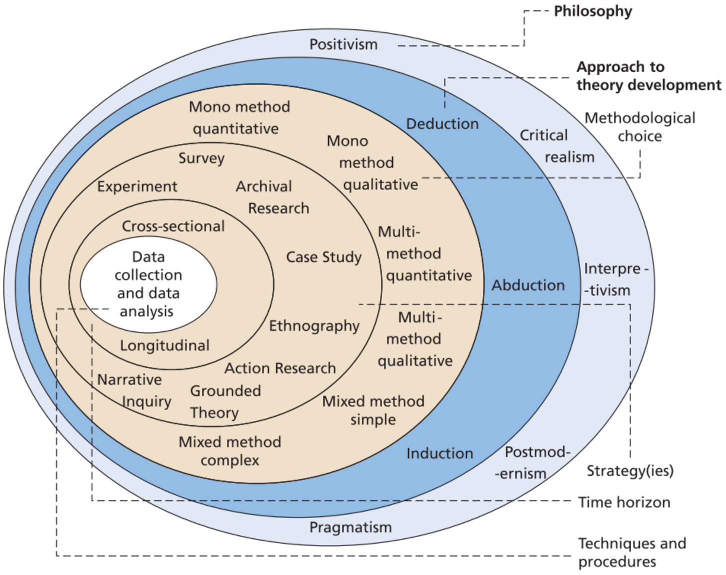


Figure 4.3: Research Onion Model
(Saunders et al., 2019)

The onion model provides a broader perspective and clear guidance for developing research design from various perspectives. The research onion provides a more detailed guide to illustrating the systematic design of a study due to its methodological structure and completeness. In this sense, the remainder of this chapter on research design considers the methodological relationships of the research components by Crotty (1998), the simplicity of the nested research methodological model by Kagioglou et al. (1998), and the broadness of the research onion model by Saunders et al. (2019). It starts with the research philosophy in the next section.

4.4 Philosophical Stance

The most important enquiry that every researcher should answer is the need to define the research philosophy and foundations. As Dainty (2008) and Creswell & Clark (2018) point out, it is vital to understand the philosophy of research at the early stages of research. Saunders et al. (2019) presented the research philosophy as the first level of their model and defined it as a perspective that reflects the worldview and structure of the theoretical beliefs underlying the research strategy. The research philosophy can be understood as a set of criteria for how and why it is necessary to influence and direct the research process (Bell et al., 2018). Basically, there are three philosophical views: ontology, epistemology, and axiology (Bryman, 2015). These assumptions must be identified as they constrain and guide the research paradigm, as stressed by Saunders et al. (2019) and Braun & Clarke (2018). Thus, research philosophy represents the following principles:

1. Ontological assumptions reflect the relationship between the world and human interactions and practices, which, therefore, mainly relate to the nature of reality.
2. Epistemological assumptions reflect the validity of knowledge, so they are primarily related to the ways or methods that should be used to explore and prove the truth.
3. Axiological assumptions relate to the effects of the researcher's values on the study, which is therefore related to the influences of the researcher.

As Gary (2014) concludes, ontology seeks to understand "what it is" (i.e. its reality or how phenomena exist in the world) while epistemology seeks to understand "what it means to know" (i.e. how knowledge is acquired about phenomena). Therefore, it is important that the researcher and the reader understand the ontological, epistemological, and axiological perspectives that have been adopted to support the nature of the study (Bell et al., 2018). The subsequent sections highlight the fundamental philosophy of research, followed by the justification of the adopted philosophical stance.

4.4.1 Ontological Stance

As previously mentioned, ontology is a methodological concept primarily used to reflect the assumptions and viewpoint of the researcher about the nature of reality; it is based on the world's relationship and human interactions (Dainty, 2008). However, there is no fixed position within the literature on the ontological stance. For example, Dainty (2008) insists that objectivist or constructivist are the two main ontological positions on the philosophical continuum. Objectivism refers to phenomena that are independently existing concepts, while constructivism explains how phenomena are constructed as a result of interaction with human perceptions so that constructors are dependent and subject to constant change. As a result, Crotty (1998) also identified subjectivism as an ontological position

In comparison, Hepburn (2003) proposed two perspectives associated with research ontology within the broader spectrum of research philosophy in the social sciences, namely realism and relativism. According to Easterby-Smith et al. (2002), because of its independent existence from human interactions, realism has a substantially objective position even though it is understood in a social context. For realist researchers, variables such as culture, tradition, and organisation exist and act independently of the observer (Gray, 2014). Relativists, on the other hand, assume that there are several realities and ways to reach them.

In this context, there seems to be a broad consensus that a realist perspective is appropriate for conducting construction management research (Dainty 2008; Crotty 1998). Thus, construction researchers seek to interpret independent reality by building human perceptions and understanding. Consequently, the research intends to understand the process of BIM adoption and the relationships among the key factors that influence BIM through the lens of professionals within Nigerian SMAFs. Therefore, reality is constructed based on the experiences and perceptions of professionals within Nigerian SMAFs; hence, the ontological position leans more towards the subjective side of the philosophical continuum. However, further justification of the adopted ontology is discussed in the subsequent section (see section 4.2.4).

4.4.2 Epistemological Stance

The underlying assumptions of epistemology relate to the acquisition of knowledge. As Creswell & Clark (2018) describe, the philosophy of epistemology is about creating and disseminating the required knowledge. This includes topics such as appropriate sources of knowledge, knowledge structure and constraints (Dainty, 2008). Creswell & Clark (2018) state that the determination of an epistemological stance is necessary to formulate precise assumptions about the manner and type of knowledge to be generated for a given study. In this respect, these assumptions fundamentally affect research methodology and potential research contributions. Additionally, Creswell & Clark (2018) argued that the two extremes of epistemological stances are positivist and interpretivist. Furthermore, Creswell & Clark (2018) stated that a *positivist epistemology* is often found within the field of natural sciences, while *interpretivism* is based on the structure of human understanding, which is formed by interactions with a phenomenon. This means that interpretations are consistent with a perspective that assumes reality is shaped by social interactions (Saunders et al., 2019). Additionally, Saunders et al. (2019) defines the philosophy of the four epistemological stances, which includes interpretivism, positivism, constructivism and pragmatism. Therefore, in the subsequent sections, these epistemological stances are presented.

4.4.2.1 Interpretivist Epistemology

The interpretive epistemology is based on the belief that individuals develop their perceptions based on their experiences, knowledge, and actions (Crotty, 1998). This suggests the opposite belief of the positivist and seeks to develop '*culturally derived and historically situated interpretations of the social life-world'* (Crotty, 1998, p. 67). Gray (2014) claims that interpretivism assumes that knowledge is what individuals consider real, without independence or a single reality. Therefore, there is no direct relationship between subjects "people" and object "world". As Crotty (1998) states, this means that the perspective of the interpretivist is based on the fact that the world is interpreted by the classification schemes of the mind. Furthermore, Gray (2014) stated that the interpretivist ontological basis falls within subjectivism or relativism. Consequently, interpretivism research must recognise that the interpretation of meaning primarily depends on the development of perceptions resulting from individual interaction with the phenomenon (Crotty, 1998). Considering that this phenomenon is based on a person's experience, interpretive researchers also tend to pursue an inductive process to conduct their research as inductive reasoning enables the establishment of large generalisation based on a specific observation (Creswell & Clark, 2018), i.e. conclusions are derived from a dataset.

However, from an organisational perspective, the interpretivist stance seems appropriate to address issues related to BIM adoption in SMAF, where complexity and inaccuracy are visible (Cunard, 2013). In this way, participants can express their assessment of the factors that influence BIM adoption within Nigerian SMAFs. Nonetheless, in the context of this research, a purely interpretivist approach might not yield the desired research conclusions as a quantitative statistical approach is essential to establish empirical evidence of the factors that influence BIM adoption within Nigerian SMAFs. Thus, a purely interpretivist epistemological stance is not suitable for answering all the research questions.

4.4.2.2 Positivist Epistemology

The objectivist ontology assumes that there is only one truth independent of the researcher, which is often compatible with the natural sciences (Cohen et al., 2013). Within the social sciences, positivists believe that social phenomena are governed and guided by specific rules and theories (Dainty, 2008), while social science research seeks to generate these theories in order to interpret them and understand an independent reality (Creswell & Clark, 2018). This means that social objects exist independent of any particular recognition by the researcher (Crotty, 1998). Thus, the existential position of positivism is objectivism because the researcher does not respond to the phenomenon while the focus remains on a reality that is real and independent (Bell, Bryman, & Harley, 2018; Gray, 2014). Positivists use deductive processes based on testing hypotheses or theories and using quantitative tools to understand this phenomenon (Gray, 2014). As a result, applying theoretical methods through deductive processes can similarly use positivism as an epistemological stance on social phenomena in the applied world. However, ignorance of critical factors can influence human behaviour and consequently the data collection (such as culture, loyalty, and experience). Indeed, Mertens (2009) criticises the use of positivist assumptions in social objects.

It can be argued that problems, such as the phenomenon of BIM adoption within Nigerian SMAFs, can be presented as a definite undertaking if the building science approach is adopted. However, when researching a phenomenon, there is often a need to account for both social and cultural aspects. Indeed, BIM adoption is a complex phenomenon (P. Li et al., 2019); it reflects the social values perceived by individuals and makes it difficult to view issues through a deductive approach. As previously mentioned, this research examines the topic of BIM adoption within Nigerian SMAFs. Therefore, the nature of this study is influenced by cultural, geographical, and environmental requirements, which in turn are socially created. The adoption of a purely positivist paradigm is therefore not entirely appropriate for answering the main enquiry of this research.

4.4.2.3 Constructivist Epistemology

Constructivists believe that social phenomena are constructed from individual perceptions, and the existence of the social world results from social interactions (Saunders et al., 2019). Therefore, a social objective is not discovered but instead constructed (Crotty, 1998). The ontological stance to constructivism is subjectivism or relativism because the constructivist researcher rejects the idea of a single reality but instead believes there are multiple realities based on time, context, and several other factors. From this point of view, Dainty (2008) argues that acquired knowledge may not represent the truth but instead reflect individual experiences. As a result, constructivists are working to narrow the gap between objectivist and subjectivist perspectives (Dainty, 2008) by following an inductive process to investigate the phenomena under study (Creswell & Clark, 2018).

This study aims to examine the perceptions of professionals within Nigerian SMAFs, which are based on experience in their practice. However, it can be argued that the investigation is based on two types of enquiries, namely social structure, and numerical underpinning, which indicates a pragmatic philosophical position.

4.4.2.4 Pragmatist Epistemology

The pragmatism paradigm, known as a “mixed or hyper methodology”, has evolved to take advantage and mitigate weaknesses within the positivist, constructivist, and interpretivist paradigms (Saunders et al., 2019). Pragmatism is based on the conviction that problems are independent, and not the methods with which they are understood (Creswell & Clark, 2018). In this respect, the claim of the pragmatist is based primarily on knowledge that prevents a precise ontological and epistemological position. This implies that, in pragmatism, researchers should utilise the philosophical and/or methodological stance most appropriate for the research problem under investigation (Tashakkori & Teddlie 1998).

The ontological position of pragmatism understands that reality might be singular, but multiple realities also exist, known as “critical realism” (Maxwell, 2008). A pragmatist recognises both objective and subjective stances because they use a range of quantitative and qualitative data to inform a phenomenon. Therefore, they apply mixed methods research and follow an abductive approach that is derived from both induction and deductive approaches (Creswell & Clark, 2018).

Within abduction, researchers often oscillate between inductive and deductive approaches and construct a theoretical perception of the phenomenon based on participants’ experience and understanding (Cohen et al., 2013). For a pragmatic epistemological stance, mixed methods are fundamental as they can provide sufficient multitasking tools to align with the depth and breadth of data collection (Creswell & Clark, 2018). Additionally, the decision to select a pragmatic approach is clarified by Higham (2014), who states that the most effective study adopts a comprehensive survey that allows for the integration of multiple perspectives. It is therefore believed that a pragmatic approach can provide an over-understanding of the phenomenon under study. It is also believed that this position allows the researcher to freely choose from a variety of research tools to accomplish the main task of this study.

To achieve the aim of the research, it is essential to achieve a sufficient understanding of the process of BIM adoption from the perspective of professionals. Thus, the pragmatic approach allows for the utilisation of mixed-method data collection tools, which ultimately provide results that not only cover a wide population but also produce in-depth knowledge of the BIM adoption process within Nigeria SMAFs. Therefore, the adoption of a pragmatic approach is most appropriate to address the aim of this research because it allows the researcher to adopt the philosophical position and/or methodological approach that best solves the research problem under investigation. In the context of this research, this means that both qualitative and quantitative approaches can be adopted to collect the data necessary to answer the research questions. For example, a quantitative approach can be utilised to provide empirical evidence and generalise the factors that influence BIM adoption within Nigerian SMAFs, while a qualitative approach can be utilised to gain an in-depth understanding of the relationship between the factors that influence BIM adoption and the BIM adoption process within Nigerian SMAFs. Therefore, although the research might lean more towards the interpretivist spectrum of the research philosophical continuum, the adopted epistemological research stance is pragmatism.

4.4.3 Axiological Stance

The axiological stance refers to the researcher's values toward the study, which plays a vital role in understanding the research findings (Saunders et al., 2019). The two extremes of the axiological stance are value-laden and value-free. In the positivism assumption, the researcher separates themself from the research data, meaning that the researcher is value-free and unbiased. As Saunders et al. (2019) stated, a valued free assumption can be attributed to data collection being independent of the researcher. Interpretivists, on the other hand, assume that the researcher is linked to the research data and thereby has an impact, thus denoting a value-laden role. Therefore, data from many social factors, such as culture, experience and perception, must be considered biased (Mertens, 2009).

4.4.4 Adopted Philosophical Stance Justification

Figure 4.4 shows the research philosophical stance continuum and highlights the adopted philosophical stance, research approach and research strategies. When understanding the philosophical stance, the two extremes of the research paradigm are social science research (which seeks to answer a research question) and pure science research (which seeks to answer a hypothesis), as shown in Figure 4.4.

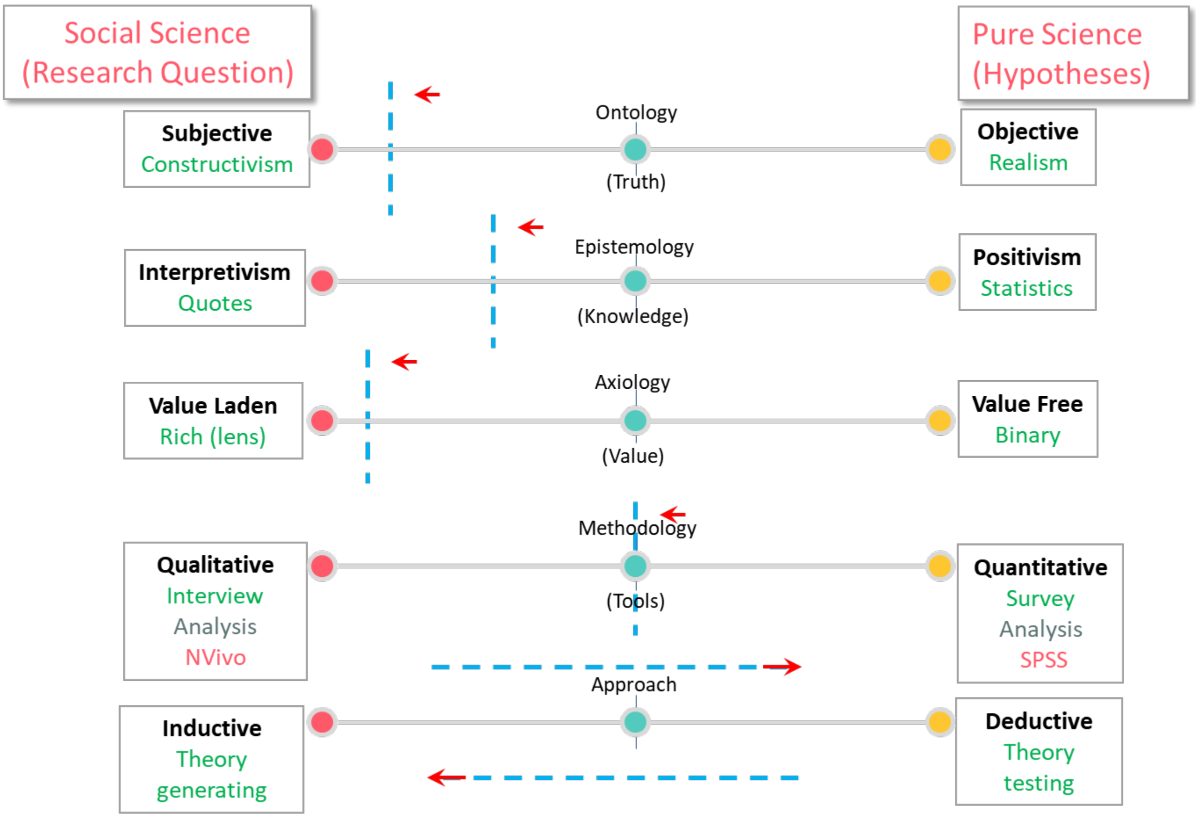


Figure 4.4: Philosophical Stance Continuum

Ontology refers to *truth*, or *what is the reality*, while the two extremes are subjective and objective. In the social science spectrum, the truth is subjective (constructivism); therefore, multiple realities exist based on individuals' perspectives of the phenomenon. For example, when an individual is asked whether the temperature in a room is warm or chill, the answer would be subjective based on the individual's perception. In contrast, pure science believes that truth is objective (realism), and there is a single reality; for example, when an individual is asked to measure the temperature of a room, the result would be the same regardless of the individual taking the measurement. In this regard, this research seeks to develop a framework to understand the BIM adoption process by analysing professionals' perceptions within Nigerian SMAFs. This means that reality is constructed based on the experience and perceptions of the individual professionals within Nigerian SMAFs.

Therefore, the ontological stance of this research leans towards the subjective (constructivism) spectrum, which aligns with a social science approach.

Epistemology refers to *knowledge,* or *how is the knowledge acquired*, and the two extremes are interpretivism and positivism. In the social science spectrum, knowledge is acquired through documents, such as verbatim quotes from interviews which are subjected to the researcher's interpretation. For example, the interpretation of a study that requires individuals' perceptions of a phenomenon would vary depending on the researcher's understanding of the data collected. In terms of the pure science spectrum, knowledge is mainly acquired through statistical data and the interpretation is consistent regardless of the researcher's interpretation. However, although the nature of this research requires the acquisition of knowledge based on individuals' experiences and perceptions of the process of BIM adoption (i.e., through qualitative data collection), there are still aspects of the study that require numerical data to statistically establish (i.e. through quantitative data collection) the extent to which certain factors influence BIM adoption within Nigerian SMAFs. Therefore, although the epistemological position of this research leans towards the interpretivism spectrum, a pragmatic approach is most suitable due to the flexibility it allows to move freely between interpretivism and positivism. This enables the researcher to combine both methods, which can alleviate both methods' shortcomings in isolation.

Axiology refers to the *value*, or *what is the researcher's value in the study*, and the two extreme stances within an axiological epistemology are value-free and value-laden. Value-free assumes that the researcher is independent of the research data collection, and this is usually binary, i.e. yes or no, one and zero. This is most common in the pure science spectrum, where statistical or numeric data are collected. For example, when collecting the temperature of a room with a thermometer, the individual would not have any influence on the numeric data collected, indicating that the axiological assumption of this research is value-free. In contrast, a value-laden axiological position assumes that the researcher influences the data collected, and this is usually understood within the spectrum of social science research. It involves the collection of rich data, which are subjective in nature. For example, when a researcher collects data based on the experiences of individuals, the individual and/or researcher's experience, culture, and perception might affect the richness or quality of the data collected. Therefore, to achieve the research objective, namely to identify the factors that influence BIM adoption and the understanding of BIM adoption within Nigerian SMAFs, the researcher needs to collect and analyse data based on the perceptions and experiences of professionals within Nigerians SMAFs. This makes the axiological assumption value-laden since the research is not independent of the research, and the data collected might be biased based on the individual's culture, experiences, and perceptions.

Considering the above justifications for the adopted research philosophical assumptions, the overall philosophical stance tends more towards the social science spectrum where the ontological assumption leans more towards the subjective spectrum, the epistemological assumption lean more towards a pragmatist approach, and the axiological assumption tends more towards the value-laden side of the spectrum. Therefore, the subsequent sections present the research classifications, methodological choices, and research approach based on these philosophical assumptions.

4.5 Methodological Choices

The methodological choices are described by Saunders et al. (2019) as a theory on how to investigate. In other words, methodology guides the research efforts. Traditional research methods have long conflicted with quantitative and qualitative research (Bell et al., 2018). Quantitative research is based on an objectivist ontological stance and a positivist epistemological stance with a deductive approach. In contrast, qualitative research has an inductive approach with a subjectivist ontological stance and an interpretivist epistemological position. As a result, quantitative research often examines scientific hypotheses in the pure science field, while qualitative research examines social phenomena in the social science field.

However, there is an increasingly controversial debate about the value of purely quantitative or qualitative research, which has led to the development of a pragmatic worldview that is not concerned with absolute unity. For many scholars (Bell et al., 2018; Creswell & Clark, 2018), quantitative and qualitative research is problematic and often leads to biases. Therefore, one solution to overcome the weaknesses of each approach while improving the overall quality of a study is to combine methodological enquiry methods within one paradigm. Pragmatic researchers are willing to look for different ways to collect and analyse evidence rather than follow a single systematic approach (Mertens, 2009). In this context, Creswell & Clark (2018) state that researchers' choices should be based on the nature of the research questions, the researchers' experience, and the audience. In the following subsections, qualitative, quantitative, and mixed-method methodologies are outlined.

4.5.1 Qualitative Methodology

Qualitative research is likely to focus on experience and human knowledge, which are usually associated with social and cultural studies. Creswell (2013b) describes qualitative research as an “inductive, interpretive and naturalistic approach” to exploring people, attitudes, phenomena and social processes in their natural environment in order to reveal the people’s perceptions of a phenomenon. Qualitative research uses a relatively small sample of participants and is based on words or textual data rather than numerical data (Braun & Clarke, 2018). With sufficient participants, qualitative research generally results in narrow but extensive data, with detailed narratives from participants (Braun & Clarke, 2018). It considers aspects of social reality and examines differences between data in order to understand and explain the nature of this phenomenon (Braun & Clarke, 2019). As Creswell & Clark (2018) point out, qualitative research can help researchers better understand complexities. Qualitative data are collected using methods such as open surveys, interviews, focus groups, observations, or ethnography (Creswell & Clark, 2018). As Braun and Clarke (2018) point out, a qualitative methodology mainly consists of two distinct branches: (i) Inductive, where the research begins with a “definitive” and ends with a general phase for which a top-down approach to the development of theories is used; and (ii) subjective, where the values of the researcher influence the research process.

Creswell & Clark (2018) suggest that a qualitative methodology has apparent advantages. A qualitative approach offers the possibility of selecting a small sample and intensely focusing on the perception of participants, which serves as the primary data source. The qualitative approach is ideal for studying complex phenomena as it provides a more detailed description of each experience. However, a qualitative methodology has its weaknesses. It may not be sufficiently accurate, lacks validity and reliability, and results are unlikely to be consistent and systematic (Creswell & Clark, 2018). Bryman (2018) noted that the generalisation of results could also be perceived as a problem affecting qualitative research results.

4.5.2 Quantitative Methodology

Quantitative research is generally associated with the natural sciences and is designed to study natural phenomena. This form of research includes a social science explanation of a phenomenon that adopts mathematical approaches. Creswell & Clark (2018) explains quantitative methodology as the empirical research of a social phenomenon or human issues through the study of theories. It consists of variables measured in numbers and analysed using statistics to determine whether or not relevant variables explain the theory. Quantitative research often examines the relationships between variables to interpret or predict a phenomenon (Bryman, 2018). The collection of quantitative data is often more comprehensive than qualitative data but offers less depth (Creswell & Clark, 2018). As a result, quantitative studies are unlikely to collect detailed, complex data. Instead, quantitative research simplifies diverse responses to generalise the results (Saunders et al., 2019). Quantitative research is attributed to two characteristics: (1) deductive, which is used to test theories because it is a top-down ascending approach; and (2) objective, which means that the researcher is separated from the research (Braun & Clarke, 2018).

In the field of social sciences, a survey technique is the most commonly used quantitative method. The advantage of adopting a quantitative survey approach is that it uses a large and more representative sample, increasing the research results' generalisability (Creswell & Clark, 2018). The data collected can also be analysed statistically via advanced software (Creswell & Clark, 2018). A quantitative approach provides a more precise summary of the critical elements of the results that can be used by other researchers (Braun and Clarke, 2018). However, quantitative methods also have weaknesses because they restrict the participants' perspectives to a predefined set of responses (Braun & Clarke, 2018). As Bryman suggests (2018), the use of such methods to examine social reality may not reflect the actual reality of participants. Creswell & Clark (2018) also note that quantitative research generally forgets participants' perceptions and understandings of the data collected, confirming that statistical samples of quantitative methods are not likely to represent perceptions of particular social groups or individuals.

4.5.3 Mixed Methodology

A mixed methodology offers an opportunity to combine qualitative and quantitative methods. As Tashakuri and Creswell (2007, p.12) noted, a mixed methodology is defined as

> *"… research in which the investigator collects and analyses data, integrates the findings, and draws inferences using both qualitative and quantitative approaches and methods in a single study or program of inquiry"*

The mixed methodology uses a research approach called the "abductive approach", which is a combination of inductive and deductive approaches (Creswell & Clark, 2018). The use of a mixed-method approach has considerable advantages since it reduces the weakness of separate qualitative and quantitative approaches by providing the researcher with the ability to be flexible and integrative (Creswell &

Clark, 2018). Furthermore, this strengthens the data collection and reinforces the research outcomes by providing the depth of the qualitative understanding and the breadth of a quantitative method (Cohen et al., 2013). Additionally, this approach is useful when a quantitative or qualitative approach alone is not enough to answer the research questions. Another advantage, as Creswell & Clark (2018) points out, is that the outcomes of the mixed-method approach are generalizable.

In light of the above, it can be argued that the wide range of philosophy and methodological tools possible enables the researcher to be more flexible when choosing the most appropriate approach to the study. Nonetheless, the subsequent section presents a justification for the adopted methodological approach.

4.5.4 Justification of the Adopted Methodological Approach

In line with the research onion model by Saunders et al. (2019), the methodological considerations for this study are based on the epistemological assumptions described above; thus, the pragmatic approach is consistent with the study's purpose. Therefore, the methodological decision that seemed most appropriate for this study is a mixed-method approach, which employs an abductive process with a quantitative method to establish statistical evidence and the sorting of emerging variables (i.e. factors that influence the BIM adoption process within Nigerian SMAFs). This is followed by a qualitative method to gain an in-depth understanding of the relationship between the factors and the BIM adoption process. It is based on the nature of the subject, which is characterised by uncertainty and complexity, requiring an explanatory approach through an abductive mixed-method process (i.e. both quantitative and qualitative methods).

The development of a framework to understand the BIM adoption process within Nigerian SMAFs requires the utilisation of a numerical statistical approach to obtain quantitative evidence and accurate results concerning the factors that influence the BIM adoption process. It also requires in-depth analysis to understand the relationship of the factors and the BIM adoption process, which can be obtained through qualitative study (i.e. through the perspective and experience of professionals within Nigerian SMAFs).

4.6 Research Strategy

A research strategy is a systematic study that can be used to conduct meaningful research that meets specific objectives. Saunders et al. (2019) assert that the research strategy must be consistent with the philosophical assumptions of the study in order to ensure coherence and harmony between the research design and thus achieve robust results. It also includes an appropriate decision on the research strategy based on the research objectives. It considers the time limit, available resources, and research experience (Bryman, 2015). A review of relevant literature shows a wide range of research strategies in the areas of knowledge. According to Saunders et al. (2019), there are five types of research strategy: experiments, surveys, case studies, movement research, and ethnography. Denscombe (2010) divides this group into the two strategies of grounded theory and phenomenology. In addition, Yin (2018) proposed including archival analysis research strategies, which significantly facilitates the research of historical events. However, Yin (2018) has been criticised for not considering essential research strategies, such as action and ethnographic research, despite their relevance. Therefore, a crucial question remains as to whether the research strategy adopted will provide the data needed to achieve the intended objectives. From this perspective, the research strategies summarised by Sexton (2003) can be integrated into a continuum of philosophical research, as shown in *Figure 4.5*.

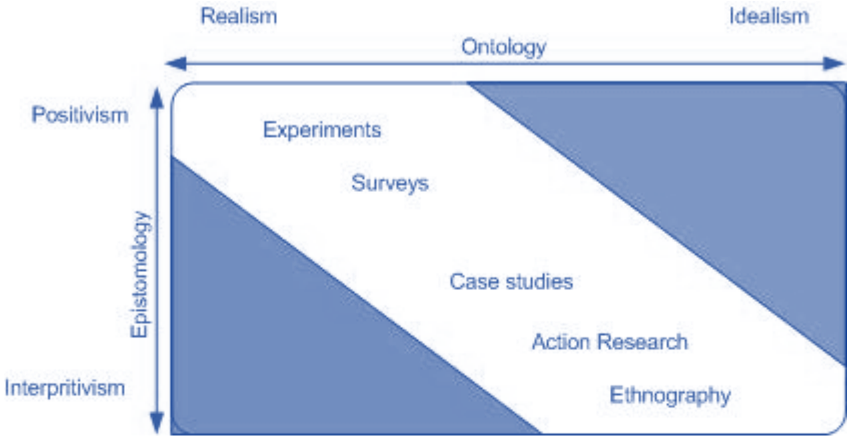


Figure 4.5: Research strategies mapped onto the philosophical stance (Sexton, 2003)

As shown in Figure 4.5, various research strategies can be applied based on the philosophical position, i.e. ontology, epistemology, and axiology. This includes experiments, action research, surveys, ethnographic approaches, and case studies. A brief overview of these strategies is presented in the subsequent sections.

4.6.1 Experimental Studies

Experimental studies are closely related to the design of scientific research. However, the term experimental study has a wide range of definitions. Experimental research, in the narrow sense, is called a true experiment (Yin, 2018). Yin (2018) identified three main types of experiments: laboratory, field and natural. In general, an experiment will study the impact of the relationship between specific quantitative phenomenon variables by controlling tools, participants and the environment. The scientific experiment is based on a hypothesis and variables manipulated by the researcher and can be measured, calculated, and compared (Yin, 2018). The data is collected, and the results are presented to determine if the hypothesis should be supported or rejected. A useful aspect of experimental research is that it is value-free and requires an objectivist position, so the results become more reliable and valid. However, since the ontological stance of this research leans more towards the subjectivist position, the use of experiments is considered unsuitable. Experimental studies are conducted in controlled environments where there is a separation between context and phenomena.

4.6.2 Survey Studies

A survey study is a valuable research strategy to the field of social science, as it involves gathering evidence from a specific sample of elements drawn from a defined population (Saunders et al., 2019). A researcher can employ several survey techniques, which can be divided into two types depending on the period and instrumentation. One method involves a questionnaire and interview, while the other consists of cross-sectional and longitudinal surveys. Cross-sectional surveys collect data at a single point in time from a sample of a specified population. This strategy is used to document the prevalence of specific characteristics in the population.

In contrast, longitudinal surveys collect additional evidence from independent samples from the same population at more than one point in time. While the main advantage of using surveys is the generation of a large amount of data, there are limitations as surveys are relatively expensive and time-consuming. However, many cost-saving methods can be implemented (Maxwell, 2008). Saunders et al. (2016) believe that surveys can test phenomena, but their ability to examine the context is doubted.

In contrast, as Maxwell (2008) reported, combining quantitative “questionnaires” with qualitative “interviews” can help the researcher to achieve different objectives. Therefore, this study is based on a survey-based strategy, as understanding the BIM adoption process in Nigeria requires the researcher to work with professionals to gain insight into their perceptions of the key factors that influence the adoption. In addition, this strategy helps to validate and disseminate research findings. Therefore, the survey-based study strategy is the most appropriate research strategy, providing sufficient evidence to achieve the research objectives. The decision to adopt a survey-based study was justified in this section by considering the nature and philosophical assumptions of this study. However, the subsequent sections provide further justification for the choice of the strategy.

4.6.3 Case Study Strategy

As defined by Yin (2018, p. 18), A case study strategy is "*an empirical investigation that examines a phenomenon in a real context, especially when the boundaries between the phenomenon and the context are unclear*." Therefore, the integration of a case study can help researchers investigate a phenomenon, and build a detailed picture of the relationships and processes within the phenomenon. The case study may provide a range of evidence from observations, documents, artefacts, questionnaires, and interviews, but, as Yin (2018) points out, this strategy is somewhat close to a qualitative approach.

According to Yin (2018), case studies can be conducted for exploratory, explanatory or descriptive purposes, whereby the researcher can use one or more case designs, namely either embedded or holistic. Yin (2018) noted that the case study strategy is appropriate for topics that relate to a range of current events, which a researcher cannot control; it allows them to examine relevant topics from different perspectives at different levels for which in-depth evidence can be generated. One of the most common critiques is that the data gathered cannot always be generalised, i.e. applied to the entire population (Saunders, 2019). This can result in a data collection bias, making it difficult to draw firm conclusions about causation and effect. One may argue that survey data could be collected during a case study approach; however, the survey is confined to selected cases (Yin, 2018), which again raises a question about generalisability. Nevertheless, although a case study approach can be utilised to achieve the objective of this research, it is still not appropriate for this study as it is necessary to generalise the research conclusions drawn from the collected data to develop a comprehensive framework for BIM adoption within Nigerian SMAFs.

4.6.4 Action Research

The purpose of action research is to contribute to the immediate resolution of practical problems and the achievement of social science objectives through cooperation in a mutually acceptable framework to improve current practices (Carr, 2006). Day et al. (2006) reported that the development of action research was founded in the domain of education. This strategy is described as an iterative action that includes a series of continuous activities, such as diagnosis, planning and evaluation, which can often consume a lot of time (Saunders et al., 2016). Participants in action research play a crucial role in designing practices to reform performance and improve their understanding (Day et al., 2006).

Bryman (2016) argued that academics criticise action research for lacking rigour and being partisan in approach. Furthermore, action research has been condemned for its lack of generalisation and objectivity and its high value-laden nature (Kock, 2005). Additionally, Saunders et al. (2016) state that, among the number of practical problems to consider when adopting action research are: the requirement to promote participation and collaboration, the researcher's position as a facilitator, and the stages or iterations involved can make action research a demanding technique due to the required intensity, time and resources. As this research aims to develop a framework to understand BIM adoption within Nigerian SMAFs, action research would not be applicable since this study has no intention of improving current BIM practices within Nigerian SMAFs through evaluating current practices by professionals. Thus, for these reasons, action research was not considered applicable.

4.6.5 Ethnography Strategy

As a research strategy in the social sciences, ethnography is used to describe individuals or small communities by considering the ethnographic researcher as a research tool. Harris and Johnson (2000, p. 13) defined ethnography as "*a written description of a particular culture - customs, beliefs and behaviour - based on information collected through fieldwork*". Saunders et al. (2019) defined an ethnographic study as a strategy that is "*highly time-consuming and [takes] place over an extended period as the researcher needs to immerse themselves in the social world being researched as completely as possible*". The ethnography research strategy is not appropriate as it tends to study participants' behavioural and physiological patterns or understand the culture of a population. Instead, this study aims to develop a framework based on empirical data from the social experience of professionals within Nigerian SMAFs.

4.6.6 Adopted Research Strategy Justification

The above discussion highlights that the research strategy depends on the type of research process involved, which includes the aim, objectives and type of results expected from the study. It also deals with the degree of control that the study of variables can play and whether the focus points to past or current events (Yin, 1994).

The focus of this study is to develop a framework based on empirical data from the social experience of professionals within Nigerian SMAFs. Assessing and examining the perceptions of professionals within SMAFs on their current BIM practices and intentions requires a social science approach; however, it is relatively complex to conduct social science research in the field of AEC compared to management research (Ghannad et al., 2019).

The review of research strategies provided insights into which would be more appropriate, namely the survey-based strategy, because it provides an avenue to collect quantitative questionnaire survey data, and qualitative interviews. The quantitative data will provide the researcher with a wide range of professional perceptions on the phenomenon, i.e. BIM adoption practices and process, while the qualitative interview data will provide in-depth evidence on the research subject, i.e. the relationships between the factors that influence BIM adoption and the BIM adoption process within Nigerian SMAFs.

4.7 Time Horizon

The time-horizon layer described by Saunders et al. (2019) was divided into two types, longitudinal and cross-sectional. The period in which the research was conducted is the primary determinant of the time horizon. A study can be categorised as longitudinal if the data is collected several times at different intervals to examine a specific phenomenon and control the development and changes over time (Saunders et al., 2019). In contrast, a cross-sectional study is limited to a specific time and phenomenon (Saunders et al., 2019). Although research instruments are distributed at different times, these techniques are of interest to the study itself. So, the approach undertaken is cross-sectional. This research, therefore, does not intend to investigate changes in a specific phenomenon over a period of time, but is tied to a doctorate timeframe, which means that the time horizon of this research is cross-sectional.

4.8 The Research Design Process

The research design is considered the general chosen strategy to integrate the different components of research in a consistent and logical way; it provides an effective solution to the research problem, and offers a detailed outline of the data collection and analysis (Bell et al., 2018). This research design is hypothetico-deductive, which means a rationale is developed to achieve each research objective by integrating data at different inquiry stages and mixing different methods (Kamdjoug et al., 2018). There are three phases in this study, which are the theoretical, empirical and framework, as shown in *Figure 4.6*.

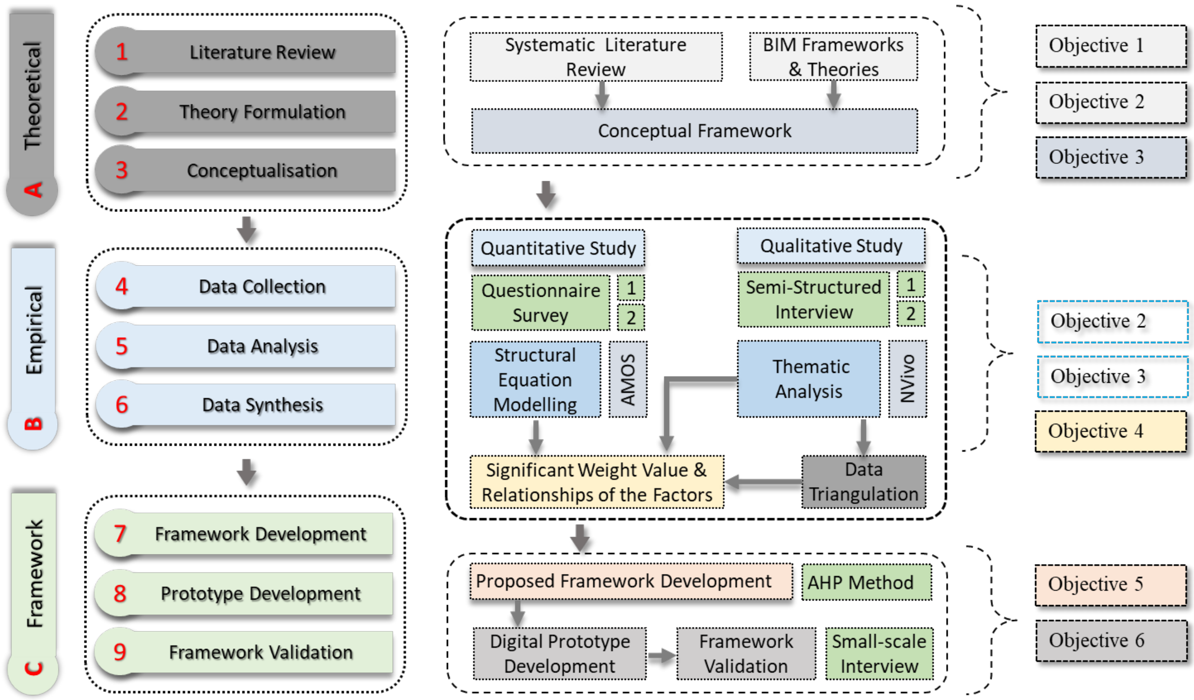


Figure 4.6: Research Design Diagram

Figure 4.6 shows the research design diagram. On the left-hand side of the research design diagram, there are nine stages of the research process, which are clustered into three phases (i.e. theoretical, empirical, and framework). Additionally, the middle section of the research design diagram maps the research process for each phase, while the right-hand side of the research design diagram provides an indication as to which objective is addressed within the research phases. Considering *Figure 4.6*, the research design discussion is presented in the subsequent sections.

4.8.1 Theoretical Phase

The theoretical phase consists of three major stages, which include the literature review, theory formulation, and conceptualisation of the research model. This stage provides an in-depth theoretical background of BIM implementation within SMEs and guides the development of the model for this study. Firstly, the literature review was both critical and systematic. This phase helps to understand previous and current studies on the construction industry, BIM and related theories, frameworks and assessment models, which achieved objectives 1, 2 and 3 of the research. Establishing the current arguments and influential factors relating to BIM adoption within SMEs further helps to identify the theories behind the adoption of BIM. Subsequently, the theoretical formulation stage incorporates relevant key elements that contribute to the research problem in order to develop a theory (Grant & Osanloo, 2014). At this stage, information from the literature review, models, and theories are integrated logically. This helped develop and conceptualise an evaluation model, which guides the research and explains the research questions by clearly identifying and labelling variables within the conceptual model (Hussey & Hussey, 1997). The evaluation model forms the basis of the conceptual model for which the proposition is to test the relationship and factors that influence BIM adoption (consisting of four clusters and 11 components) in the first instance. It is subsequently used to structure the framework development process.

4.8.2 Empirical Phase

The empirical phase consists of three stages, namely data collection, data analysis and data synthesis. The primary data collection methods to be adopted in this study (as previously discussed) are a quantitative questionnaire survey and qualitative interviews. The conceptual model is generated during the theoretical phase and will guide this. The questionnaire involves contacting professionals within Nigerian SMAFs through an online platform and by hand delivery. The questionnaire helps identify firms with a relatively advanced BIM capability, which is used to select firms for the interview. The target population is represented by 600 SMAFs, which are registered with the Architects Registration Council of Nigeria (ARCON). The sampling design and sample size are essential considerations in establishing the representativeness of the sample and its generalisability; therefore, reviewing a similar study shows that sample sizes larger than 30 and less than 500 are appropriate for most research since there is no standard sample size for a questionnaire survey (Bryman, 2016). However, a discussion on the sample size calculation and population sample is presented in the subsequent sections (*see section 5.2).*

The interviews conducted among the selected firms will be based on prescribed criteria (a respondent's interest in further participating in the study after the questionnaire survey). This research will gather valuable information based on the experiences of architectural professionals in the Nigerian construction industry. Perry's (1998) study shows there are no precise guidelines for the total number of cases for inclusion but recommends more than four cases because, "*with fewer than four cases, it is often difficult to generate theory with much complexity, and, its empirical grounding is likely to be unconvincing."* (Eisenhardt, 1989, p.545).

The data will be collected from two primary sources of empirical data, namely a survey and interviews. The survey data, which aggregates quantitative evidence, will be statistically analysed using multiple regression analysis within the SPSS statistic package to test the hypothesis, evaluate the model, and ensure stability among the responses. The outcome offers a relative weight value for the indicators and provides statistical evidence of the relationship between variables. However, the in-depth-interview will be analysed thematically using a qualitative analysis tool (NVivo) to transcribe, code and create themes for pairwise comparison of the semi-structured interviews. This thematic analysis method allows the researcher to make sense of the data and visually understand the shared meanings and experiences (Braun et al., 2019). At the synthesis stage, the different sources of collected data are evaluated and analysed to achieve the ultimate aim of the research, which is to develop a framework for the BIM adoption process within Nigerian SMAFs.

4.8.3 Framework Phase

The framework development phase involves a three-step approach: framework development, prototype development, and validation. At the framework development stage, findings from the data analysis and discussion of both the quantitative and qualitative studies are carefully and logically used to formulate the framework to understand the BIM adoption process within Nigerian SMAFs. The framework is developed by establishing the structure and then the priorities of the factors. The prioritisation is achieved through an AHP process, which entails a pairwise comparison approach to the set of factors identified by their influence on the BIM adoption process within Nigerian SMAFs. Additionally, the BIM adoption framework is instrumental to the prototype development stage as this forms the basis of the information utilised during the development process of the prototype.

The prototype development stage is an ideal way to develop an interactive digital prototype of the framework for Nigerian SMAFs, which intends to facilitate the use and application of the proposed framework in practice. However, to successfully achieve the objective of the prototype development stage, three main steps are considered. These steps include research and planning, wireframe design and coding, and prototype publishing and testing. Consequently, the validation is the final stage of the framework phase. In the validation stage, the trustworthiness of the BIMAF development process is assessed. Therefore, the validation process aims to check the operational validity process rather than an absolute validity process because, as Sargent (1998) argued, it is impossible to achieve absolute validity. Considering this, a small-scale interview guided by a set of validation criteria is conducted with a group of experts on the subject (i.e. the BIM adoption process in Nigerian SMAFs). The result of the validation output will confirm the practical implications and usefulness of the framework and provide further recommendations to the study.

4.9 Research Design Credibility

Assessing the credibility of the research design will enhance the reliability and validity of research results. Regardless of the methodology adopted, reliability and validity are integral parts of the credibility of the research design (Miles & Huberman, 1994). Although May, Hunter, & Jason (2017) believed that no research method is inherently superior to any other, Golafshani (2003) argued that finding value by combining various sources of information enhances the credibility of the research output. Thus, the concept of methodological pluralism. A pluralistic study is often referred to as a mixed-method study where two or more methods (qualitative and quantitative) of data collection are used (May et al., 2017).

However, similar to methodological pluralism, data triangulation is a strategy to improve the validity and reliability of research or evaluation (Bell et al., 2018). Additionally, Webb et al. (1966) suggested that the triangulation process provides the most compelling evidence because uncertainty in the interpretation of research output is significantly reduced due to the confirmation of research output by two or more independent measurement processes. Similarly, Bryman (2016) affirmed that triangulation, which refers to the use of multiple methods to investigate a research question, increases the level of confidence in the resulting conclusions.

Consequently, this study uses a sequential concept of methodological pluralism and the triangulation of data by combining several data collection methods to reach a more appropriate research conclusion (see *Figure 4.6*). Therefore, the credibility of this research is ensured by adopting a pluralistic approach to gathering and evaluating information from the critical review of extant literature, the quantitative questionnaire survey, and the qualitative interview study to provide a comprehensive set of results.

4.10 Research Techniques and Procedure

This section presents the research data collection techniques and analysis procedures. In this research, a mixed-method approach is adopted that sequentially conducts both quantitative and qualitative methods. Therefore, the following sections will present the research data collection and analysis procedure for the quantitative survey study and the qualitative interview study.

4.10.1 Quantitative Survey Study

The survey method is chosen as it effectively collects data, where a study defines the requirements and measurement of variables (see section 4.6.6). Questionnaires are often used to measure experimental design variables, comparative surveys, and field studies (Bell et al., 2018). In addition, Nigerian SMAFs have different characteristics, and the information needed concerns a specific demographic group. Furthermore, the advantage of the questionnaire method is that it simultaneously administers questionnaires to a large population, which is less expensive and takes less time than an interview (Field, 2018).

However, this method presents problems associated with confidentiality (Longacre & Hussey, 1997). As a result, the study used participant consent information to inform participants and ensure that the data collected were anonymous and considered highly confidential. In addition, although questionnaires can be administered by mail, hand or by using online methods/tools, the online method/tool is adopted due to the inefficiency of mail services in Nigeria (Kori, 2015). Furthermore, although the questionnaire survey was administered before the global pandemic, the impact of Covid 19 made administering the questionnaire through an online platform more desirable and safer due to global lockdowns and health concerns. The questionnaire administration method for this research is presented in the quantitative study chapter (s*ee Section 5.2*).

4.10.2 Questionnaire Analysis Procedure

The quantitative analysis of this research is conducted in two parts and analysed using descriptive analysis and inferential analysis. The first entails descriptive analysis, which considers the reliability of the data collected, the respondents' demography and background, while the second part contains the inferential analysis (such as correlation, factor analysis and multiple regression), which explores the empirical relationship of the factors that influence BIM adoption within Nigerian SMAFs. Furthermore, SPSS, which is statistical software, is utilised to clean, code and present the data from the respondents to ensure it is ready for the descriptive and inferential analysis (see Appendix 8 for the code book). Additionally, the cleaned data are transferred into AMOS software, which is recommended for SEM (Field, 2018). Considering this, the subsequent section discusses the statistical measurement tools, analysis method and analysis techniques.

4.10.2.1 Statistical Measurement Tool

The questionnaires, from which the quantitative data are obtained, are analysed using various statistical tools; these are compatible with the measurement tool used in the design of the questionnaire. The Likert scale, a commonly used measurement tool, is the most commonly used method of scaling data in questionnaires to provide several options in which respondents make their choices (Field, 2018). Recognising that such an approach limits the ability of respondents to express their position and thereby limits the responses (Yin, 2014), it is likely that the reliability of the survey technique is improved (Field, 2018). The questionnaire developed for this phase of the study uses open-ended questions with a hierarchy for levels of agreement to allow respondents to express some of their opinions that are not captured in the options given.

Saunders et al. (2019) suggested that it is likely that lower-level Likert scale provides higher mean scores than other adopted methods of measurement, such as higher-level Likert scales (for example, 10 level scales). Furthermore, Saunders et al. (2019) stated that it could allow participants to clearly express their perceptions with a reasonable degree of consistency with the data provided. The choice can be justified for three reasons. Firstly, it is much easier for the researcher to analyse the data, focus potential participants on the data provided, and answer the questions carefully. The second reason is to allow a reliable comparison with previous trials that have followed similar techniques (Croasmun & Ostrom, 2011; Ivanov et al., 2018; Joshi et al., 2015). Third, the primary objective of the questionnaire is to refine and consolidate the conceptual model developed from the literature. Therefore, in this phase of the questionnaire, a five-point scale (i.e. strongly disagree, disagree, neutral, agree, and strongly agree) is adopted. To calculate the relative weighting of responses, Saunders et al. (2019) suggested that degree 1 is assigned to “strongly disagree”, while degree 5 is assigned to “strongly agree”. *Table 4.2* shows the five Likert scales and their assigned values.

Table 4.2: The five Likert scale and assigned values

Scale	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Value	1	2	3	4	5

Considering Likert’s measure, the numerical data gathered from the survey are analysed using ‘descriptive’ and ’inferential’ statistics, as Saunders et al. (2019) recommended.

4.10.2.2 Statistical Analysis Method

According to Croasmun & Ostrom (2011), descriptive statistics are a statistical analysis method for describing attributes in the social sciences. The descriptive analysis includes frequency distributions, central tendency measures (such as mean and median), and dispersal measures (such as standard deviation) (Joshi et al., 2015). Non-parametric tests are used because the instrument provides (the Likert scale) an ordinal measure for examining the degree of agreement and disagreement over each given subject. Furthermore, Saunders et al. (2019) stated that the three most common tools used for measurement in descriptive statistics are the mean, median and standard deviation. However, this research does not just require fundamental descriptive statistical analysis but also inferential statistical methods capable of estimating multiple relationships between variables, such as the factors identified as influencing BIM adoption within Nigerian SMAFs. On the other hand, *inferential Statistics* (advanced analysis) go beyond the data's central tendency and are used to analyse correlations, differences, and trends in numerical data (Saunders et al., 2009). Therefore, using inferential statistics, the data may be examined to determine the strength and significance of the relationships between variables (i.e. the relationship between the factors that influence BIM adoption within the Nigerian SMAFs).

Considering this, the quantitative analysis aims to validate the conceptual model developed from the literature review and provide empirical evidence of the relationship between the variables in the conceptual model. Furthermore, the data received from the online questionnaire will be used to validate and refine the conceptual model. Thus, descriptive and inferential statistics are utilised to interpret the findings of the online questionnaire due to the following:

1. Descriptive analysis is used to summarise the data set in terms of the average, mean, median, and standard deviations, which represent a sample of the population or the entire population. Therefore, the demographic information of respondents and the reliability of the data is analysed using descriptive analysis.

2. Inferential analysis is used to provide an estimate of the strength of the relationships between variables for this study, which includes the factors that influence BIM adoption and the level of BIM adoption based on the company size and BIM maturity level.

4.10.2.3 Statistical Analysis Techniques

According to Pallant (2016), statistical techniques can be divided into two main types.

(i) As techniques used to explore the differences between groups through statistical analysis techniques, such as T-test, ANOVA, MANOVA, and ANCOVA, and

(ii) As techniques used to explore the strength of the relationship among variables, such as correlation, partial correlation, multiple regression, and component analysis.

Therefore, an overview of the various statistical analysis techniques is presented in the following section.

4.10.2.3.1 Exploring differences between groups

T-tests are used to compare the mean score on a continuous variable between two groups (e.g. males and females, BIM adopters and non-adopters, small firms or large firms). The two categories of t-test are the paired sample and the independent sample. Paired sample t-tests (also known as repeated measures) are used to compare scores between participants tested at Time 1 and Time 2 (often after some intervention or event). In this situation, samples are related since data are collected from the same group of individuals during Time 1 and Time 2. Independent sample t-tests are used to compare two different (independent) groups of people (BIM adopters and non-adopters). In this scenario, data are collected from two different groups simultaneously, and therefore, the samples are unrelated. The non-parametric alternatives of these tests are the Mann-Whitney U Test and the Wilcoxon Signed Rank Test.

The analysis of variance (ANOVA) is similar to the t-test. However, it is used to compare the mean scores of two or more groups on a continuous variable. The *one-way analysis of variance* enables the researcher to examine the relationship between one independent variable and one dependent variable. In contrast, *the two-way analysis of variance* enables the researcher to examine the relationship between two independent variables and a single dependent variable. ANOVA reveals how the groups differ but do not reveal the group's significant difference. Furthermore, by utilising planned comparisons, the researcher can choose to evaluate differences between certain groups rather than comparing all of them. Additionally, the Kruskal-Wallis and Friedman tests are non-parametric alternatives.

The *multivariate analysis of variance* (MANOVA) is used to compare groups on a range of distinct but related dependent variables; for example, comparing the effects of various treatments on a variety of outcome measures (e.g. anxiety, depression). Multivariate ANOVA is applicable to one-way, two-way, and higher factorial designs with one, two, or more independent variables.

The *analysis of covariance* (ANCOVA) is used to statistically adjust for the effects of a confounding variable (covariate). This is advantageous when it is hypothesised that groups differ on a variable that could influence the independent variable's impact on the dependent variable. To ensure that the influence is being exerted by the independent variable, ANCOVA statistically eliminates the effect of the covariate. ANCOVA can be used in conjunction with a one-way, two-way, or multivariate design.

4.10.2.3.2 Exploring Relationships

Pearson correlation or Spearman correlation is utilised to investigate the strength of a link between two continuous variables. This indicates the relationship's strength as well as its direction (positive or negative). A positive correlation means that, when one variable increases, the other also increases, whereas a negative correlation means that as one variable increases, the other decreases.

Partial correlation is an extension of Pearson correlation, which allows for the control of the effects of another confounding variable. The influence of the confounding variable (e.g. a socially desirable response) is removed in partial correlation, resulting in a more accurate picture of the relationship between the two variables of interest.

Multiple regression is a more advanced version of correlation that is used to investigate the capacity of a group of independent variables to predict one continuous dependent measure. Using various forms of multiple regression, the predictive power of independent variables can be evaluated to determine the optimal combination of variables that predict a dependent variable.

Factor analysis enables the reduction of a huge number of variables or the scaling of items down to a manageable number of factors (i.e., categories, components, or criteria). Summarising the underlying correlation patterns and searching for 'clumps' or groups of strongly linked elements accomplishes this. This technique is frequently used to ascertain the underlying structure of scales and measurements.

Discriminant function analysis is used to explore the predictive ability of a group of independent variables on a single categorical dependent variable. That is, to determine which variables most accurately predict group membership. In this scenario, the dependent variable is typically a distinct criterion (passed/failed, discontinued/continued treatment).

Structural equation modelling is a relatively new and highly complex technique to test multiple models of the interrelationships between a set of variables. It uses multiple regression and factor analysis techniques to determine the significance of each independent variable in the model and to evaluate the model's overall fit to the data. Additionally, it enables a comparison of various models.

In light of the above overview of the various statistical analysis techniques, ANOVA, MANOVA, and ANCOVA are appropriate for analysing how a group differs but does not reveal significant differences. This would be appropriate if the study was focused on examining the difference between groups, such as BIM adopters and non-adopters within Nigerian SMAFs. However, this study aims to establish empirical evidence of the relationship between the factors that influence the BIM adoption process within the Nigerian SMAFs. On the other hand, Correlation, Multiple Regression, and Factor Analysis are capable of not only analysing the relationship between variables (dependent and independent) but also provide the strength and direction of the relationship, which is what the questionnaire survey aims to achieve. For example, factor analysis can summarise the factors based on their correlation patterns and the strength of the relationship between groups. Furthermore, although *discriminant function analysis* can be used to determine which independent variable accurately predicts a dependant variable, the criterion is usually distinct (i.e. pass or fail, yes or no). This is unlike *Structural Equation Modelling* (SEM), which evaluates the interrelationships between a set of variables using multiple regression and factor analysis to determine the significance of each independent variable. Thus, the advantage of SEM over the discriminant function analysis and its ability to utilise and combine correlation, factor analysis and multiple regression to analyse the interrelationship between variables makes it appropriate for the quantitative study (i.e. to evaluate the relationship between the factors that influence the BIM adoption process within Nigerian SMAFs).

4.10.2.4 Structural Equation Modelling

SEM is a multivariate technique combining aspects of multiple regression (examining dependence relationships) and factor analysis (representing unmeasured concepts-factors with multiple variables) to simultaneously estimate a series of interrelated dependent relationships (Mueller & Hancock, 2018). SEM also integrates other techniques, such as recursive path analysis, non-recursive econometric modelling, ANOVA, analysis of covariance, principal component analysis and classical test theory (Jichuan Wang & Wang, 2019). In addition, SEM is also known as path analysis with latent variables and is now regularly used to represent dependency (arguably "causal") relations in multivariate data for the behavioural and social sciences (Mueller & Hancock, 2018). In this research, the relationship among constructs that were developed in the conceptual model chapter (*see section 3.5*) need to be established; SEM is a statistical methodology that takes a confirmatory approach to the analysis of a structural theory relating to a phenomenon with two or more important aspects (Mueller & Hancock, 2018).

The development of advanced technological tools for data management and statistical analysis allows researchers to efficiently perform a variety of statistical analyses (Saunders et al., 2019). In this study, the statistical analysis was conducted with two different statistical software packages: SPSS, which allows the researcher to process complex data in a timely and straightforward manner, and AMOS, a structural equation modelling software that allows simultaneous multiple variable analysis, such as confirmatory factor analysis among others.

Accordingly, Field (2018) advocated that SEM is appropriate for performing inferential analysis techniques to simultaneously estimate interrelated causal relationships, such as multivariate analysis, path analysis and factor analysis. Therefore, unlike other statistical tools, such as SPSS, AMOS, which is used for SEM, allows for a graphical representation of the relationship between multiple variables when performing analysis. This makes it easier to understand the analysed variables, such as the factors that influence BIM adoption within Nigerian SMAFs.

4.10.3 Qualitative Interview Study

The qualitative interview method is essentially utilised during: (i) the main qualitative study with participants within Nigerian SMAFs, and (ii) the validation process of the BIM adoption framework and digital prototype with experts in the field of BIM. In the main qualitative study, the interview study aims to understand the relationship between the factors that influence BIM adoption and the adoption process within Nigerian SMAFs. However, during the interview phase, a pairwise comparison between the factor categories and their associated components is also conducted using the analytic hierarchical process (AHP) to prioritise the factors that influence BIM adoption within Nigerian SMAFs. The interview method is achieved through semi-structured interviews with professionals within Nigerian SMAFs until the *saturation point* is reached. The second interview will be conducted during the framework validation process stage and is a semi-structured interview with experts on BIM within Nigerian SMAFs. This aims to validate the developed framework and digital prototype for BIM adoption. Thus, the analysis techniques of the collected data from the interview process are discussed in the next section.

4.10.4 Interview Analysis Procedure

Braun, Clarke, Hayfield, & Terry (2019) defined thematic analysis as a means to identify, organise and present a systematic overview of insights into the meaning of patterns (themes) across the dataset. The study uses this method to focus on the meaning of the interview data set, as it facilitates an understanding (thematic analysis) of collective or shared experiences (Braun et al., 2019). Therefore, this method also allows for the identification and understanding of commonalities in the BIM adoption processes of Nigerian SMAFs with similar levels of BIM maturity, based on the interview verbatim transcript. Although a detailed description of the interview analysis process is presented in the qualitative study discussion Chapter (see section 6.2), the semi-structured interviews are transcribed verbatim manually and transferred/entered into a qualitative analysis software package called "NVIVO 12". However, when analysing the transcribed verbatim interviews, an inductive approach or deductive approach can be utilised. According to Caulfield (2020), an inductive approach allows the data to dictate the themes, whereas a deductive approach means approaching the data with preconceived themes, which are anticipated to reflect prior theory or the knowledge gathered. Accordingly, this research (sequential mixed approach) starts with a quantitative study and subsequently a qualitative study. However, the purpose of the interview analysis is to conduct an in-depth analysis of the current BIM status of Nigerian SMAFs, their understanding of BIM, and the influence of the identified factors on the process of BIM adoption within Nigerian SMAFs in order to ultimately develop an appropriate framework for BIM adoption. Therefore, the qualitative study utilises preconceived themes, which emanate from the empirical findings of the quantitative study via the semi-structured interview analysis. For this reason, the study adopts a deductive thematic analysis approach to analysing the interview data.

Having discussed the methodological stance, research design, credibility, techniques and procedure, it is important to adhere to ethical practices when conducting this research. Therefore, the next section presents the ethical considerations included during this research process.

4.11 Ethical Considerations

The nature of this research involves human participants, and as such, consideration of all critical and necessary ethical issues is incorporated. Furthermore, Saunders et al. (2019) suggested that ethics are critical and should be considered for any research project to be successful. Whether the researcher collects secondary data or primary data via interviews or questionnaires, it is essential that before commencing the research, the study is scrutinised and approved as adhering to ethical guidelines. Hence, guided by the UK Research Integrity Office Code of Practice for Research (UKRIO, 2018), this research gained ethical approval from the Research Ethics Committee of the University of Salford in October 2018 (see Appendix 1). The ethical activities presented to the committee included: the participant information sheet, details of the nature of the research, rights of the participants, and privacy issues. For the questionnaire study, participants were contacted through their professional bodies, as discussed in the previous sections. The online questionnaire consisted of a mandatory section that detailed the nature of the research (through a participant information sheet) and requested the consent of each participant before granting permission to proceed. Similarly, the interview participants were contacted through their email addresses with attached forms; consent form (see Appendix 5), participant information sheet (see Appendix 6). Hence, the participants were required to complete and sign the forms prior to commencing the interview process to ensure that participants were aware of the nature of the research and consented to participation.

4.12 Chapter Summary

The philosophical and methodological considerations that underpinned the research were justified. A pragmatic approach, in line with an abductive approach and facilitated by an explanatory sequential mixed methodology, proved to be appropriate for the nature of this study, which aims to develop a framework to understand BIM adoption within Nigerian SMAFs. Against this backdrop, a quantitative questionnaire survey and qualitative semi-structured interviews techniques were identified as the preferred research tools for gathering the data required to develop a robust and contextual framework for BIM adoption within Nigeria SMAFs. Furthermore, methodological pluralism (and the triangulation of data) is adopted to increase the credibility of the research. Furthermore, a three-phase research design process that includes a theoretical, empirical, and framework phase is utilised to discuss the chosen research strategies. The theoretical phase consists of a critical review of extant literature, theory formulation, and the conceptualisation of the model. The second phase is empirical, which entails the data collection, analysis, and synthesis stages. The third phase is the framework, which consists of the framework development, prototype development, and the validation process stages, which assesses the research quality to determine the extent to which the research outcome reflects the phenomenon under study. Finally, the ethical issues considered for this research were discussed.

5 Chapter Five – Quantitative Study

5.1 Chapter Overview

In the previous chapter, the philosophical underpinnings and approach to this research were extensively discussed. This chapter presents the quantitative research, which is the first part of the sequential, mixed-method approach adopted for the study (see section 4.8.2). The quantitative study aims to validate the conceptual model and establish empirical evidence of the key factors influencing BIM adoption within Nigerian SMAFs. Additionally, this serves as the first step towards understanding the relationship between the factors (variables) that influence BIM adoption within SMAFs and offers a basis for exploring these factors through the qualitative study. Thus, this chapter presents the questionnaire design, pilot study, response rate, preliminary data analysis, model measurement analysis; model construct estimation and model validity measurement.

5.2 Questionnaire Design

The main aim of the questionnaire was to elicit normative evidence of the key factors that influence BIM adoption within Nigerian SMAFs, as opposed to opinion-based data (e.g. gathering perceptions or understanding meaning), as this sort of data would advocate the use of closed questions (Field, 2018). Large-scale views were desirable to obtain the perceived importance and establish statistical evidence of the significance of key factors that influence BIM adoption. To manage this, the questionnaire was split into four key sections covering the various categories of factors (i.e. organisational capability, individual competence, environmental control, and technological quality) as identified through the critical review of the literature. In addition, a section was included related to the demographic data about participants, job role, firm size, experience and region.

A copy of the suggested questions was sent to the supervisory team in the middle of March 2019. Based on the comments of the supervisory team, the demographic questions were adjusted, and further questions were included. Once the questionnaire was approved, the questionnaire was issued in a digital format via an online survey application platform. It was designed to take approximately fifteen minutes to complete. This aspect is crucial because it has been shown that participation in research is heavily influenced by the amount of effort required on the participant's part (Field, 2018). The first page of the questionnaire carried a full explanation of the purpose of the questionnaire, a mandatory checkbox for participant consent and a checkbox for participants to indicate their willingness to be contacted for the next phase of the study (interview); the latter gave a single-line text box in which interested participants could provide their contact information. Subsequent pages presented the demographic information and four main categories, which were on separate pages with a brief definition of each. A pilot study was then conducted after the questionnaire was designed.

5.2.1 Sampling Design Process

The two categories of sampling techniques are probability and non-probability sampling procedures are as shown in Figure 5.1.

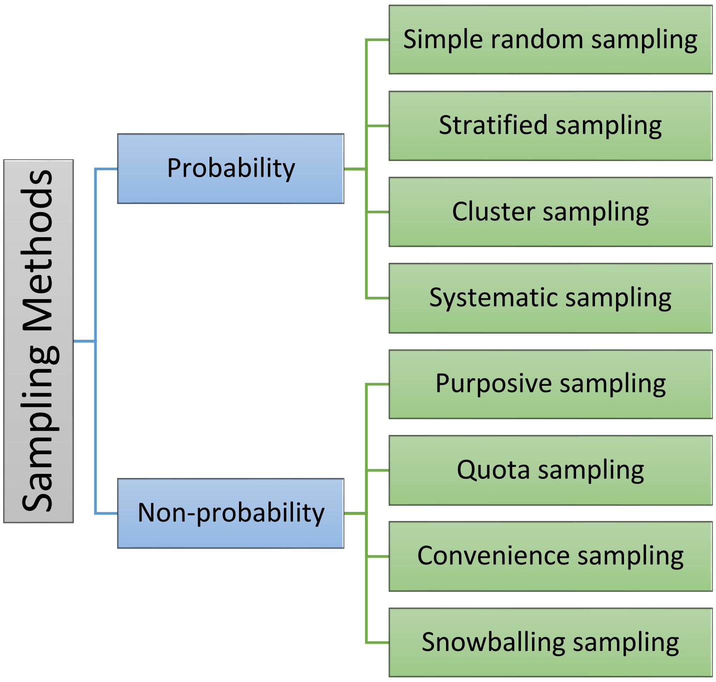


Figure 5.1: Sampling Method

According to Tochrim (2002), in the probability sampling technique, samples are picked at random while samples are not chosen at random in the non-probability sampling technique. Furthermore, Hair Jr et al. (2013) stated that with probability sampling, every responder has an equal chance of being chosen, whereas in a non-probability sample, a respondent is purposefully selected based on a set of criteria. In this research, the survey sampling followed a four-step process as shown in the Figure 1.1. These steps are:

A. Identify the targeted population.
B. Establish the appropriate sample frame.
C. Choose the most suitable sampling technique.
D. Calculate the sample size.

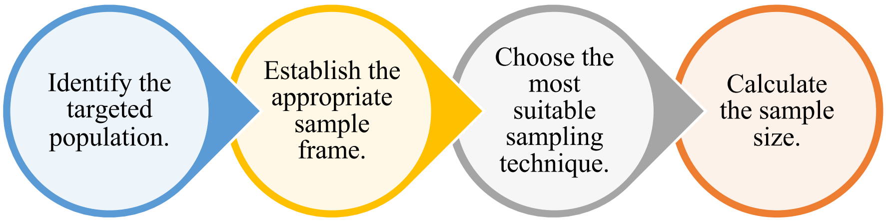


Figure 5.2: Sampling Design Process

The target population of this research is the Nigerian SMAFs as mentioned and justified in section 1.5 (research scope and boundary). Therefore, identifying the target population and determining the sample size was straightforward. Accordingly, the **sample source** was obtained from the architectural registration council of Nigeria (ARCON, 2017) document which had a total of 975 registered architectural firms. Therefore, the total number of registered firms with ARCON from the document obtained represented the **total targeted population.**

However, from the 975 registered architectural firms, only 600 firms had publicly available contact information which represented the **sample population (N)**. Therefore, based on the convenience of accessibility, the 600 firms were selected to represent the **study population (Np)**. Salkind (2014) argued that 20% of the entire population is deemed adequate for a research objective. However, for this research, because the available population number is low, all the 600 available sample were chosen. Additionally, Saunders (2009) added that it is acceptable when a convenient and achievable sample of the entire population is available. Furthermore, simple random sampling is less expensive, more efficient, and produces a more representative sample, simple random sampling was chosen.

Tabachnick and Fidell (2013), established a technique for finding the required sample size based on the number of independent variables: $N \geq 50 + 8m$ (where m is the number of independent variables). Furthermore, one of the most common suggestions for sample size is Nunnally and Bernstein's (1994) rule of 10. As Collier (2020) affirmed, 5 – 10 observations per indicator is necessary when analysing a structural equation model. On the contrary, Stevens (2012) opined that around 15 observation per indictor are required for a valid equation in a social science research. However, to identify the appropriate sample size, Krejcie and Morgan (1970) presented a formula used in computing the required sample size. Consequently, based on the above data, below is the calculated required sample size for this study.

$$S = \frac{X^2\ NP(1-P)}{d^2\ (N-1) + Xp\ (1-P)}$$

S = Required Sample Size

X^2 = the value of chi-square from the table using one degree of freedom at (3.841)

N = The population size

P = the population proportion

d = degree of accuracy (0.05).

$$S = \frac{3.841 * 600 * 0.5\ (1-0.5)}{0.05^2\ (600-1) + 3.841 * 0.5\ (1-0.5)}$$

$$S = \frac{3.841 * 600 * 0.5\ (1-0.5)}{0.05^2\ (599) + 3.841 * 0.5\ (1-0.5)}$$

$$S = \frac{576.15}{2.46} = 234.21\ \approx \mathbf{235}$$

From the above calculation, 235 is the required sample size for this study. Thus, in the subsequent section, the questionnaire piloting process is discussed.

5.3 Questionnaire Piloting

The questionnaire survey pilot was conducted with a small group of participants to evaluate the clarity and comprehensiveness of the questionnaire and the feasibility of the survey as a whole (Field, 2018). Furthermore, the pilot survey aimed to reduce subsequent difficulties for participants by identifying, demystifying, and eliminating all suggestive or biased questions. Following the suggestions of Schindler & Cooper (2006), the pilot survey was completed by colleagues, and actual participants; this helped to test the context and content of its design, investigated the precision of the questions asked, and established relevant questions to ensure the required information was gathered and the questionnaire finalised. However, prior to conducting the pilot study, the proposed questionnaire was presented during a BIM workshop at the University of Birmingham within the last quarter of 2018. This allowed experts from the field to give valuable feedback. The questionnaire was piloted up to the beginning of March 2019 through an online survey platform, and gained feedback back 40 participants; this helped to determine the final version.

As a result of the analysis of the pilot survey responses, the questionnaire was taken through a process of revision to make it more suitable for the main questionnaire survey. From the feedback provided by respondents, it was evident that the questionnaire as a whole functioned well even though some themes were adjusted based on participants' recommendations; this made it easier to move from one theme to the next through the questionnaire. Some of the terms were also re-worded as feedback from respondents seemed to suggest that they found them ambiguous. As expected, the average time taken to complete the questionnaire was approximately 15 minutes. However, some respondents recommended reducing the number of questions if possible. Hence, some questions were merged, and some were discarded. Although the questionnaire was more concise, the variables included were not reduced.

In addition, piloting the study allowed the chance to test the reliability of the instrument by employing Cronbach's Alpha (Field, 2018). Cronbach's Alpha is widely used in social sciences, and is the most common measure of internal consistency namely 'reliability'; it is mainly used for questionnaires that utilise a Likert scale for the question responses (Yin, 2018). Cronbach's Alpha ranges from 0 to 1; the measurement tool is more rigorous if this indicator is closer to 1. Hence, Table 5.1 below shows the different values of the Cronbach's Alpha test for the four main categories of factors in the study.

Table 5.1: Pilot Questionnaire Cronbach's Alpha Reliability

	Categories	Cronbach's Alpha	No of Items
1	Organisational	0.91	12
2	Individual	0.91	11
3	Environmental	0.85	10
4	Technological	0.86	09
	Total	0.95	42

In Table 5.1, the value of Cronbach's Alpha coefficient is high for each category of factors in the study, and ranged between 0.85 - 0.91. The overall Cronbach's Alpha coefficient for the data set is 0.95, indicating excellent reliability and internal consistency, as indicated by (Field, 2018; Collier, 2020). This confirms the stability of the results, their harmony with the statistical analysis in terms of objectivity, and encourages the acceptance and truthfulness of the outputs targeted. Hence, having pre-tested the questionnaire, and finalised its the development, it was ready for deployment once the sampling plan had been designed.

5.4 Questionnaire Response Rate

To encourage a good response rate, three steps were followed in administering the survey, as recommended in Creswell & Clark (2018). The potential participants were first contacted through an invitation email, which included information about the research aim and structure, the criteria for selecting participants, and the approximate time taken to answer the entire questionnaire. The second step was a follow-up email about the actual questionnaire. This was undertaken about one week after the advance-notice email. The final step involved the email of another set of questionnaires to all non-respondents. This was also undertaken about a month after the second step. Ultimately, 273 (6.5:1 – meaning that 6.5 observations per indicator) usable responses were received from participants, with no missing responses as the online questionnaire was designed to prompt respondents to complete all required questions.

5.5 Preliminary Data Analysis

As previously mentioned, the main aim of the research is to develop a framework to understand BIM adoption within Nigerian SMAFs. The evaluation process for the research follows the same structure as the conceptual model. However, the aggregated quantitative data from the questionnaire survey was statistically analysed and presented. In this manner, the data analysis first reported the respondents' background, then the reliability test, and finally, the model estimations of the variables (factors identified to influence BIM adoption). All techniques are discussed in the subsequent sections.

5.5.1 Background of the Survey Respondents

The first part of the questionnaire analysis established the quality of the questionnaire sample by analysing basic factual data relating to the respondents' professional status and demographics. This included their professional background, years of experience and size of the firm based on the number of employees. The importance of participant information and demography cannot be overemphasized. The profiling of participants can produce valuable data that is easily sorted and organised to give insights into the understanding and perspectives of each group. For this research, it is essential to understand the perspective of BIM based on the respondents' professional backgrounds. The results of the respondents' characteristics, showing both the frequencies and percentages of their responses, are aggregated in Table 5.2, while the discussion is presented in the subsequent subsection.

Table 5.2: Questionnaire Demographic Results Summary

Feature	Variables	Frequency	Percentage
Job Role	Architect	210	75.5
	Project Manager	21	7.6
	Site Supervisor	19	6.9
	BIM Specialist	14	5.0
	Others	14	5.0
Firm Size	0 – 10	63	22.6
	11 – 50	184	66.3
	51 – 250	25	9.0
	250+	6	2.2
Experience	0 – 5 years	61	21.9
	6 – 10 years	116	41.7
	11+ years	101	36.4
Region	North-Central	129	46.9
	South-East	3	1.1
	South-West	45	16.4
	North-East	18	6.5
	North-West	78	28.4
	South-South	5	1.8

5.5.1.1 Respondents' Positions

As shown in Table 5.2, the data analysis showed that the respondents were architects, some of which had different job titles. The data revealed that of the 273 valid respondents, 75.5% of the respondents defined themselves as architects, followed project managers at 7.6%, site supervisors at 6.9%, and BIM Specialists and Other job roles, such as draftsmen, designers and animators, at 10%. Although this study is mainly concerned with architects, all job titles and description were included in the questionnaire survey in order to (i) allow participants to have the freedom to choose their professional job title in order to easily identify the demography of their job description, and (ii) gain some insight as to their perception on the subject matter (BIM adoption within SMAFs). However, this result implies that, the questionnaire captured and reflected the perception and understandings of architects who had a practical understanding of the focus area since the respondents were all architects by profession despite some holding different job titles and descriptors. Furthermore, this also implies that the strategy that the researcher adopted in disseminating the survey to reach the target audience was successful.

5.5.1.2 Respondents Firm Size

More importantly, as shown in Table 5.2, the data analysis of the returned questionnaires revealed that the majority of participants (66.3%) came from firms with 11-50 employees (medium firms), while approximately 22.6% were from firms with 0 - 10 employees (micro firms) and 9.0% belonged to medium firms with 51 - 250 employees. Although six respondents (2.2%) identified as coming from large firms, with over 250 employees, it is worth noting that the majority of the responses (97.8%) were from the small and medium firms for which the number of employees was below 250. Thus, the respondents' results indicate that the target audience were consulted and therefore aligned with the scope of the research, which focuses on Nigerian SMAFs (s*ee section 1.5*). However, since the scope of the study focuses on Nigerian SMAFs, only SMAFs responses were included in the analysis process.

5.5.1.3 Respondents' Level of Experience and Region

Accordingly, the results also showed that 21.9% of the respondents had between 0 to 5 years of experience, and 41.7% had between 6 to 10 years. Moreover, 36.4% had more than 11 years in the profession. This implies that the majority of respondents had sufficient experience in the area studied to provide reliable data, which contributes to the credibility and robustness of the results. Geographically, the distribution of respondents showed that the sample represents various Nigerian geopolitical zones since roughly 54% of the respondents indicated they were from the North-Central region, 24% from South, the remaining 22% were from the other Northern parts of Nigeria; only three respondents were undefined. As expected, this result, to some extent, affirms the reported distribution of the population in Nigeria by Kori & Kiviniemi (2015) study, which established that the majority of the states with relatively high levels of IT-based practice are; North-Central (Abuja the capital territory of Nigeria); North-West (Kaduna, Kano, Katsina); and South-West (Lagos), among others.

5.5.1.4 Summary of Respondents' Backgrounds

The primary objective of this section was to develop a demographic profile of the respondents. The majority of the questionnaire survey responses emanated from architects who are sufficiently experienced to answer the questionnaire items, which gives robustness to the study's findings. The demographic data collected revealed that the majority of the survey respondents are considered within the scope of the research (i.e. Nigerian SMAFs). While the survey respondents were predominantly based in the North, it also covers various Nigerian regions, strengthening the reliability of the expected findings.

5.5.2 Constructs Reliability Test

The reliability analysis using the internal consistency method was first examined to ensure that the Likert scale rating adopter for measuring the factors yields the same result over time. Therefore, it was recommended that researchers assess the extent of the calculated internal consistency reliability on the scale generated (Yin, 2014; Field, 2013). However, as discussed earlier (see section 5.3), Cronbach's Alpha is widely used for reliability measurement, ranging from 0 to 1. The closer the Alpha is to 1, the more reliable the internal consistency of the factor in the scale. SPSS statistical software was used to establish this analysis. Table 5.3 below summarises the Cronbach's Alpha results for each category of the factor.

Table 5.3: Cronbach's Alpha Reliability Test

	Categories	Cronbach's Alpha	No of Items
1	Organisational	0.91	12
2	Individual	0.90	11
3	Environmental	0.85	10
4	Technological	0.86	09
	Total	0.95	42

Table 5.3 above shows the Cronbach's Alpha coefficient of the total categories scoring 0.945, which corresponds with the results obtained from the pilot study, which had a total score of 0.952. However, as suggested by (Field, 2018), the result has excellent reliability and internal consistency, and the respondents replies were based on a clear and shared understanding of the questions in the questionnaire. Thus, the results of the research findings are reliable.

5.6 Model Measurement Analysis

To estimate the structural model, there is a need to measure the fitness of the model. Therefore, in this section, the fitness of the model will be presented. The first section uses the standardised and unstandardised estimates, and the second section uses the squared multiple correlations. Further discussion is presented in the following sub-sections.

5.6.1 Confirmatory Factor Analysis

As previously mentioned in Section 5.2.10.3, the factor analysis permits the reduction of a large number of variables or the scaling of items to a manageable number of factors (i.e., components, or criteria). However, exploratory factor analysis (EFA) is the initial stage in establishing whether an indicator measures several constructs. As a result, the researcher does not specify which indicators are used to measure a construct. The approach attempts to load each indicator on each construct. This is where 'cross loading' occurs, in which an indicator has a significant correlation with more than one construct.

In comparison, a CFA does not permit an indication to be loaded on several constructs. As a result, the researcher will set the indicators for each construct prior to conducting the study, and those indicators will load solely on that specific construct. Another distinction between an EFA and a CFA is that an EFA is generally conducted using correlation matrices, which might pose difficulties when comparing parameters across samples.

In this research, the main purpose of the quantitative study is to validate/confirm and establish empirical evidence of the relationship between the factors that influence BIM adoption within Nigerian SMAFs, including the variables (i.e. indicators and construct). Thus, following the structure of the conceptual model established in Chapter 4, the researcher set the indicators for each construct for this analysis. In this regard, CFA appears more appropriate to determine how well the indicators measure the unobserved variables; validate the factors identified through the critical review of the extant literature, and determine how the factors influence BIM adoption within Nigerian SMAFs.

5.6.1.1 Confirmatory Approach

Confirmatory Factor Analysis (CFA) is a statistical technique that determines how effectively your indicators measure your unobserved constructs and whether they are uniquely distinct from one another. An unobservable construct is commonly referred to as a ‘factor’ in a CFA. Thus, in this research, the term ‘factor’ refers to an unobservable component that is under measurement. A circle or oval represents an unobserved variable in a diagram. The indicators that measure the unobserved variable will have single-headed arrows connecting them to the unobserved construct. A square or rectangle is used to symbolise each indicator. The single arrow connecting the factor, or unobservable construct, to the indicator, shows the unobservable construct’s effect on its indicators. Furthermore, *statistical estimates,* referred to as ‘factor loadings’, estimates the direct effect of unobservable constructs on their indicators and are interpreted as unstandardised or standardised regression coefficients (Collier, 2020). The factor loadings discussion is presented in the subsequent section.

5.6.1.2 Factor Loadings

Factor loading estimates are interpreted as *unstandardised* or *standardised regression coefficients* (Collier, 2020). The standard AMOS method for calculating parameter estimates is called the maximum likelihood and provides estimates with highly desirable characteristics (Mueller & Hancock, 2018). In an unstandardised model, regression weights, covariations, variances and intercepts (only in analysing mean structures) are displayed in the path diagram. Regression weights represent the effect of one or more variables on another (Byrne, 2013). In contrast, squared multiple correlations and standardized regression weights are displayed in a standardized model (Hayduk, 1987). However, the choice of identification constraints will not affect the standardised regression weights and correlations since they are both independent of the units in which all variables are measured (Byrne, 2013). Furthermore, Collier (2020) stated that only the standardised estimates are presented in a CFA result table. Thus, in this chapter, the standardised regression weights included in the CFA analysis table will be utilised to evaluate the factors that influence BIM adoption within Nigerian SMAFs.

5.6.1.3 Squared Multiple Correlations (SMC)

According to Collier (2020), fit measures inform the extent to which the model is fit for the data, while the strength of the structure paths in the model is determined by square multiple correlations (SMC). Therefore, SMC is the ratio of the variance that predictors consider. Simple regression uses one predictor of the dependent variable, while multiple regression uses two or more predictors (Byrne, 2013). Therefore, this research must consider the SMC for each dependent variable and adopt appropriate measures to better describe the structural model (Byrne, 2013). SMC interpretation is similar to R^2 statistics in multiple regression analysis, which is a useful statistic independent of all units of measurement (Mueller & Hancock, 2018). In this research, the SMC is especially useful to determine the strength of the model variables (i.e. indicators and construct) and provides insights as to what extent one variable (e.g. indicator) may explain or influence another variable (e.g. construct).

5.6.2 Model Fit and Fit Statistics

Model evaluation is among the problematic issues related to structural equation modelling (Mueller & Hancock, 2018). Therefore, it is essential to understand how to evaluate the models before analysing the structural models. According to Collier (2021), there is a lot of disagreement on the cut-off criteria for the fit indices. However, the most generally referenced research is Bentler & Bonett (1980), which encourages researchers to pursue model fit statistics (CFI, TLI, NFI, IFI) greater than .90. Although academics, such as Hu and Bentler (1999), claimed that the .90 threshold was too lenient and that the fit index needed to be greater than .95 in order to be considered a good-fitting model, this rule of thumb became widely accepted. Marsh et al. (2004) subsequently argued against the strict Hu and Bentler criteria favouring instead the employment of different indices based on sample size, estimators, or distributions. As a result, there are no universally applicable golden standards when it comes to model fit. According to Kline (2011), even if a model is regarded as an acceptable fit, this does not imply that it would adequately explain the relationships in the model. However, it is important to understand that model fitness is an important first step towards establishing the preliminary proof that the model adequately describes the estimated relationships. Thus, this section describes the fit measure for evaluating the model which includes the goodness of fit, parsimony, population discrepancy-based measures, Root Mean-Square Error of Approximation (RMSEA), and other related measures as discussed in the following sub-sections.

5.6.2.1 Parsimony Measures

A high parsimony (simplicity) value indicates a relatively high degree of freedom and a few parameters, while the model with relatively low degrees of freedom and many parameters indicates a lack/low parsimony, which means the model is complex. Many measures of fit attempt to reconcile these two contradictory goals: simplicity and goodness of fit. The degree of freedom (df) is a suitable method used in parsimony measurements.

5.6.2.2 Discrepancy Function Minimum Sample

CMIN (chi-square statistic ($\chi 2$)) is the minimum deviation value. In the case of maximum likelihood estimation, CMIN contains a chi-squared statistic. The number of chi-squares is a general measure of the difference between implied moments and sampling moments. The more the implied and sample moments differ, the larger the chi-square statistic and the more substantial the evidence against the null hypothesis.

The p-value is the probability of a significant deviation in the current sample based on reasonable distribution assumptions and the correctly specified model. Therefore, p is the ‘p-value’, which tests the hypothesis that the model fits perfectly with the population. As such, this is a method of identifying the model by testing the hypothesis to remove all models that do not match the available data.

5.6.2.3 Baseline Model Comparison

Three essential indicators are the Normal Fit Index (NFI), Tucker Lewis coefficient (TLI) and the Comparison Fit Index (CFI). According to Collier (2020), the CFI, TLI and NFI should fall within a range of 0 to 1. Additionally, Mueller & Hancock (2018) stated that the closer the values are to 1, the better the model fit indicated. However, for the RMSEA, a value of 0.08 or less indicates an adequate fit, while greater than 0.1 indicates a poor fit (Byrne, 2013). Table 5.4 shows the summary of the adopted measure for this research and several indicators for the fit measures.

Table 5.4: Measure of fit adopted for the research
(Collier, 2020)

Fit Measures	Fit Measures’ Indications
Chi-square (χ^2)	This requires a non-significance test result. A significant test result means the observed and estimated covariance matrices are significantly different.
RMSEA	This is the badness of fit measure. Values less than 0.08 are acceptable, but a preferred result is less than .05.
CFI, TLI and NFI	These are all comparative statistics. Values over 0.90 mean you have an acceptable model fit.

5.6.3 Understanding Diagram Symbols

Diagrams and symbols are used to represent the correlations/relationships that are examined in SEM. Therefore, it is important to understand what these diagram symbols denote since AMOS requires a conceptual model to perform estimations and analysis. Considering this, the main diagram symbols that are frequently used in SEM, according to Collier (2020), are outlined as follows:

5.6.3.1 Latent Variable / Construct

A latent variable is also known as 'unobservable'. This is an idea that cannot be observed directly. It would be ideal to just look at a firm and reveal the extent to which factors, such as organisation capability or individual competence, influence their BIM adoption process. However, the truth is that these factors are complex and not straightforward. As a result, notions like BIM adoption are 'unobservable', and the researcher needs to find another way to capture the concept by asking survey questions. When referring to latent/unobservable entities, the term 'factors' is sometimes used. Thus, the diagram's graphical representation of unobserved/latent variables or constructs is denoted by a circle or oval shape.

5.6.3.2 Observed Variable / Indicators

As the term implies, steps are conducted to capture an unobservable concept through observable means. This can be accomplished through the use of survey questions, manipulations, or behavioural tracking. This idea is also known as Manifest Variables or Reference Variables. To represent observed variables, the phrases 'items' and 'indicators' are frequently employed. Observed variables/indicators, in essence, are the raw data acquired that will be utilised to describe ideas in an SEM model. The variables/indicators observed can be categorical, ordinal, or continuous. Therefore, the diagram's graphical representation of the observed variable or indicator is denoted by a square or rectangle.

5.6.3.3 Measurement Error / Residual Terms

Measurement error represents the unexplained variance of an indicator measuring its respective latent construct. In addition to the indicator, the dependent latent construct has an error term. This is the unexplained variance at the construct level that results from the independent variable relationships. Latent variable error terms are also known as residual terms or disturbance terms. AMOS recognises measurement error and residual terms as unobserved variables since they represent unexplained variance. As a result, the error terms are represented by a circle and a one-way arrow.

5.6.3.4 Direct Path Effect and Covariances

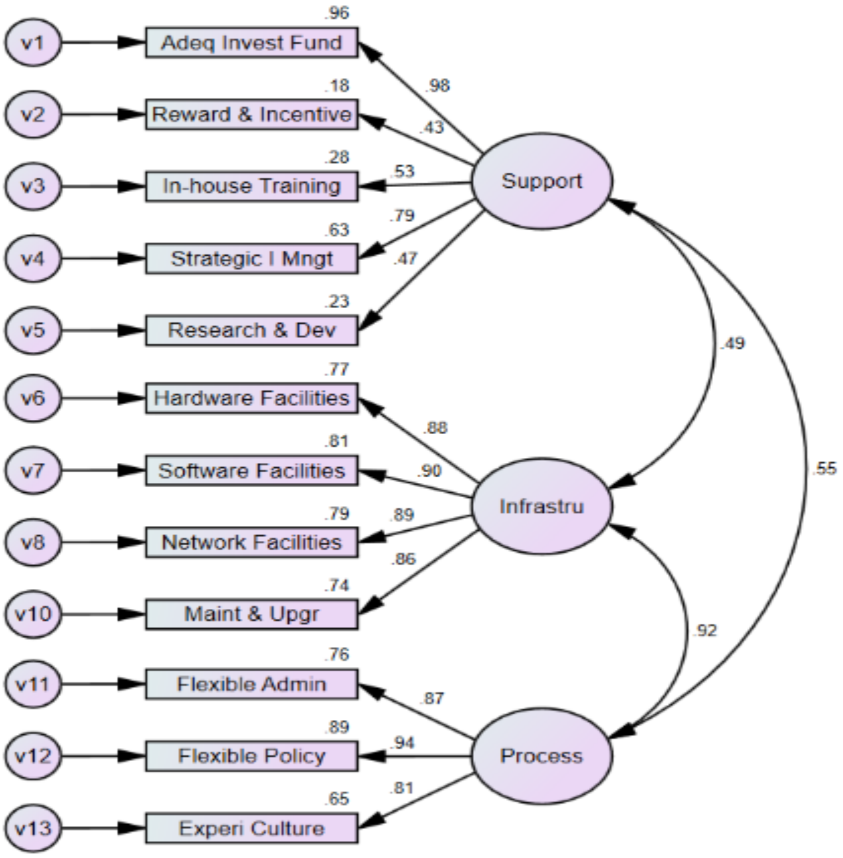
The direct path effect shows the directional effects of one variable on another, which is represented by a line and a single arrowhead. The covariances show the amount of variation in one variable proportional to the variation in another variable (the degree to which the two variables change together on a reliable and consistent basis). Thus, the covariances are represented by a curved line with two arrowheads in the diagram.

5.7 Model Constructs Estimation

From the conceptual model developed (see section 3.5), there are 42 identified indicators for 11 constructs which are clustered into four categories, namely: organisation capability (*OC*), individual competence (*IC*), environmental control (*EC*), and technological quality (*TQ*). This section evaluates the conceptual model based on the data collected to empirically establish these factors' impact on BIM adoption within Nigerian SMAFs. Thus, the model estimation of the constructs is presented in the subsequent sections, which entails the confirmatory factor analysis of each construct, the factor loadings (i.e. the standardised estimates) and square multiple correlation R^2, and the associated model fitness and fit statistics analysis.

5.7.1 Organisational Capability

The organisational capability (*OC*) category consists of three latent constructs (unobservable variables), as shown in the *OC* model diagram in Figure 5.3. These three *OC* constructs include Support (five indicators - adequate investment fund, reward & incentives, inhouse training, strategic management, and research & development), IT Infrastructure (four indicators - hardware facilities, software facilities, network facilities, and maintenance & upgrade of facilities), and Process (three indicators - flexible administrative schemes, flexible policy schemes, and flexible experimental culture).



Endogenous Latent Constructs:
Support = Management Support, **Infrastru** = IT Infrastructure, **Process** = Process and Policy

Figure 5.3: Organisational Capability Estimates

Furthermore, Figure 5.3 summarises the standardised estimates (factor loadings), the correlation between the constructs, and the indicators. The estimates or factor loadings range between 0 to 1, where the closer the value is to 1, the greater the indicator’s strength on the construct (Collier, 2020). As such, comparing the regression weights of the indicators across the Management Support (MS) construct, the strength of the effect of the indicator on the construct, from the strongest to the weakest, is: adequate investment funds (.98), strategic management (.79), inhouse training (.53), research & development (.47), and reward and incentives (.43). In regard to the IT Infrastructure construct, the strongest to the weakest indicators are software facilities (.90), network facilities (.89), hardware facilities (.88), and maintenance & upgrade of facilities (.86). Similarly, the estimates of the Process and Policy construct revealed the strength of the indicators from the strongest to the weakest to be: flexible policy schemes (.94), flexible administrative schemes (.87), and flexible experimental culture (.81).

Table 5.5 presents the CFA result of the Organisational Capability category. This CFA result consists of the three constructs and their associated indicators, the composite reliability (CR), the standardised factor loadings, the t-value and the model fit statistics indices (i.e. χ_2, df, p-value, CFI, TLI, NFI, RMSEA). Furthermore, the CFA result of the *OC* constructs and describes the extent to which each indicator relates to their associated construct, while the correlations and covariance estimates are utilised to calculate and establish the convergent validity (5.8.1) and discriminant validity (5.8.2) of the *OC* constructs.

Table 5.5: Organisational Capability Confirmatory Factor and Reliability Analysis

Constructs	*Standardised Factor Loading*	*t-value*
Management Support (C.R. = 0.74)		
The provision of the following to support BIM:		
○ Adequate investment funds – (OC_MS_1)	0.98	07.47
○ Reward and incentive schemes – (OC_MS_2)	0.43	***
○ In-house training schemes – (OC_MS_3)	0.53	06.20
○ Strategic management schemes – (OC_MS_4)	0.79	07.30
○ Research and development schemes – (OC_MS_5)	0.47	05.83
IT Infrastructure (C.R. = 0.93)		
The availability of the following to support BIM:		
○ Digital hardware facilities – (OC_II_1)	0.88	20.93
○ Digital software facilities – (OC_II_2)	0.90	22.14
○ Network facilities – (OC_II_3)	0.89	***
○ Maintenance and upgrade of facilities – (OC_II_4)	0.86	20.14
Process and Policy (C.R. = 0.91)		
The availability of the following to support BIM:		
○ Flexible administrative system – (OC_PP_1)	0.87	17.34
○ Flexible policy system – (OC_PP_1)	0.94	19.40
○ System for experimentation culture – (OC_PP_1)	0.81	***

Model Fit Statistics (χ_2 = 355.25, df = 51, p = 0.00; CFI = 0.90, TLI = 0.91, NFI = 0.93, RMSEA = 0.05)

C.R. = Composite Reliability

** = Items constrained for identification purposes.

Therefore, as shown in

Table 5.5, the CR of Management Support (.74), IT Infrastructure (.93), and Process and Policy (.91) indicates that the data reliability is acceptable. Furthermore,

Table 5.5 provides insight into how the constructs are captured by presenting the actual wordings of the indicators of each construct, as presented in the survey, to give insight as to the strength (strong or weak) of the relationship between the indicators' associated constructs. Accordingly, indicators with factor loadings below the recommended value of .70 contribute little to the understanding of the construct (Collier, 2020). Therefore, the indicators for the *IT Infrastructure* and the *Process and Policy* constructs all have strong relationship values denoting that they significantly contribute to the understanding of the constructs with regards to BIM adoption within Nigerian SMAFs. However, within the *Management Support* construct, two indicators - including adequate investment funds to support BIM (.98) and strategic management schemes to support BIM (.79) - have strong relationships with the construct, which indicates that they significantly contribute to the understanding of the construct. Moreover, three indicators, namely reward & incentive scheme to support BIM (.43), research & development to support BIM (.47), and inhouse training scheme to support BIM (.53), have a weak loading or relationship with the Management Support construct, denoting that they contribute little to the understanding of the Management Support construct in regard to BIM adoption within Nigerian SMAFs (see marked figures in

Table 5.5).

Furthermore, Collier (2020) suggests that unique indicators with weak relationships to their construct might affect another construct. In this case, reward & incentive schemes and in-house training were identified as effective ways to encourage employees to generate ideas, increase innovation, and thus support BIM adoption (Lu and Sexton, 2009). Therefore, the weak factor loading of reward & incentive schemes and inhouse training schemes might result from the indicators exerting a significant influence on the Employees construct within the IC category. Similarly, although a research & development scheme to support BIM adoption was identified in the literature, the low factor loading that indicated a weak relationship with the Management Support construct might be because Nigerian SMAFs do not recognise this indicator as relevant when adopting BIM. Nonetheless, a research & development scheme to support BIM might be helpful when trying to understand other constructs. Thus, the indicator will be further investigated in the qualitative study to understand the potential reason for the result.

Additionally, the t-value and probability measure how many standard deviations our coefficient estimates are from 0; values further from zero indicate a relationship exists. As shown in

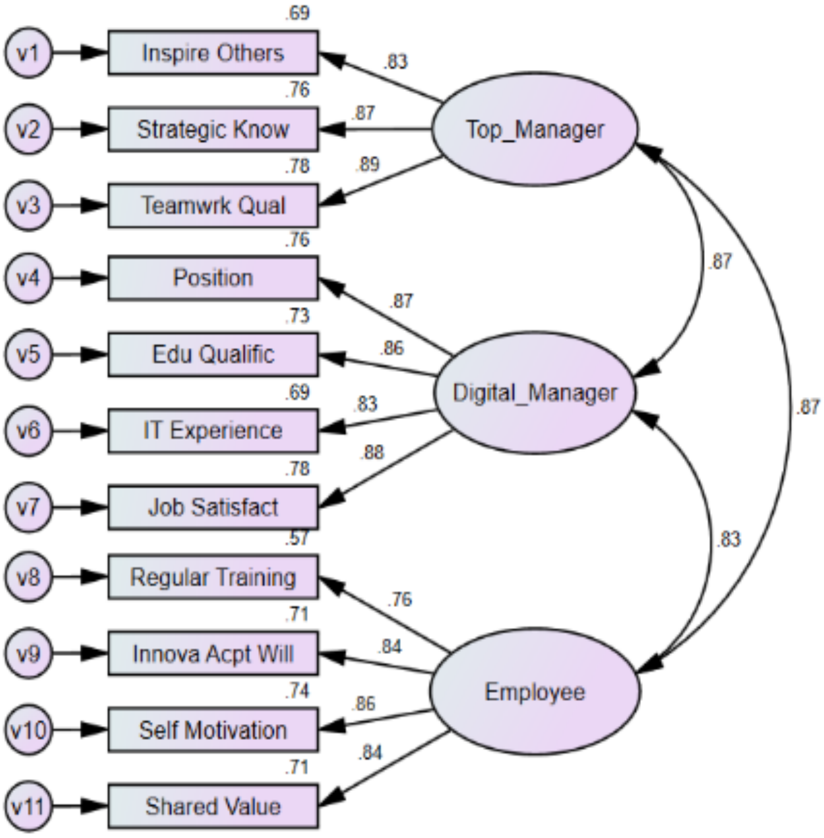
Table 5.5, the highest t-value is OC_II_2, which denotes that the probability of getting a critical ratio as significant as 22.142 in absolute value is less than 0.001. In other words, the regression weight for OC_II_2 (the provision of digital software facilities to support BIM) in the prediction of IT Infrastructure is significantly different from zero at the 0.001 level (two-tailed). Thus, it can be declared that a relationship between the OC_II_2 and the IT Infrastructure construct exists. Consequently, based on the positive t-values, which are all above 0, as shown in

Table 5.5, the relationship between the indicators and their associated constructs is evident.

Furthermore, from the 'Model Fit Statistic' output, it is observed that the relative chi-square fit test is just above 1.0, which means an acceptable fit is achieved. Also, the comparative fit indices of CFI, TLI and NFI are all above .90, further supporting the model's fit to the data. Lastly, the RMSEA value is .05, providing additional support that the model 'fits' the data. Conclusively, from this CFA, there is evidence that our indicators are measuring their intended concept, except for three indicators (OC_MS_2, OC_MS_3, and OC_MS_5).

5.7.2 Individual Competence Analysis

The individual competence (*IC*) category consists of three latent constructs (unobservable variables), as shown in the IC model diagram in Figure 5.4. These three *IC* constructs are: Top_Manager (three indicators: ability to inspire others, strategic knowledge, and teamwork quality), Digital_Manager (four indicators: position status, educational qualification, IT experience, job satisfaction), and Employee (four indicators: regular training, willingness to accept innovation, ability to self-motivate, and shared value).



Endogenous Latent Constructs:
Top_Manager = Top Manager, **Digital_Manager** = Digital Manager, **Employee** = Employees

Figure 5.4: Individual Competence Estimates

Furthermore, Figure 5.4 summarises the standardised estimates (factor loadings), and the correlation between the constructs and indicators. The estimates or factor loadings range between 0 to 1. The closer the value to 1, the stronger the indicator's strength on the construct (Collier, 2020). As such, comparing the regression weights of the indicators across the Top Manager (TM) construct, the strength of the effect of the indicator on the construct, from the strongest to the weakest, is: teamwork quality (.89), strategic knowledge (.87), and the ability to inspire others (.83). However, with regards to the Digital Manager (DM) construct, the strongest to the weakest indicator is as follows: job satisfaction (.88), employment position or status (.87), educational qualification (.86), and IT experience (.83). Similarly, the estimates of the Employee (E) construct revealed the strength of the indicators (from strongest to weakest) to be: self-motivation (.86), shared value (.84), willingness to accept innovation (.84), and regular training (.76).

Table 5.6 presents the CFA result of the Individual Competence category. This CFA result consists of the three constructs and their associated indicators, the composite reliability (CR), the standardised factor loadings, the t-value and the model fit statistics (i.e. χ_2, df, p-value, CFI, TLI, NFI, RMSEA). Furthermore, the CFA result of the IC constructs and describes the extent to which each indicator relates to their associated construct, while the correlations and covariance estimates calculate and establish the convergent validity (6.6.1) and discriminant validity (6.6.2) of the *IC* constructs.

Table 5.6: Individual Competence: Confirmatory Factor and Reliability Analysis

Constructs	*Standardised Factor Loading*	*t-value*
Top Manager (C.R. = 0.90)		
The top manager's:		
◦ Ability to inspire others – (IC_TM_1)	0.83	18.28
◦ Strategic knowledge of innovation – (IC_TM_2)	0.87	20.08
◦ Quality of teamwork – (IC_TM_3)	0.89	***
Digital Manager (C.R. = 0.92)		
The digital manager's:		
◦ Position – (IC_DM_1)	0.87	17.98
◦ Educational qualification – (IC_DM_2)	0.86	17.51
◦ Previous IT experience – (IC_DM_3)	0.83	***
◦ Job Satisfaction – (IC_DM_4)	0.88	18.27
Employee (C.R. = 0.89)		
The employees with:		
◦ Regular training – (IC_E_1)	0.76	14.91
◦ A willingness to accept innovation – (IC_E_2)	0.84	17.71
◦ Self-motivations – (IC_E_3)	0.86	***
◦ Innovative shared value – (IC_E_4)	0.84	17.71

Model Fit Statistics (χ_2 = 374.38, df = 41, p = 0.00; CFI = 0.94, TLI = 0.98, NFI = 0.97, RMSEA = 0.07)
C.R. = Composite Reliability
** = Items constrained for identification purposes.

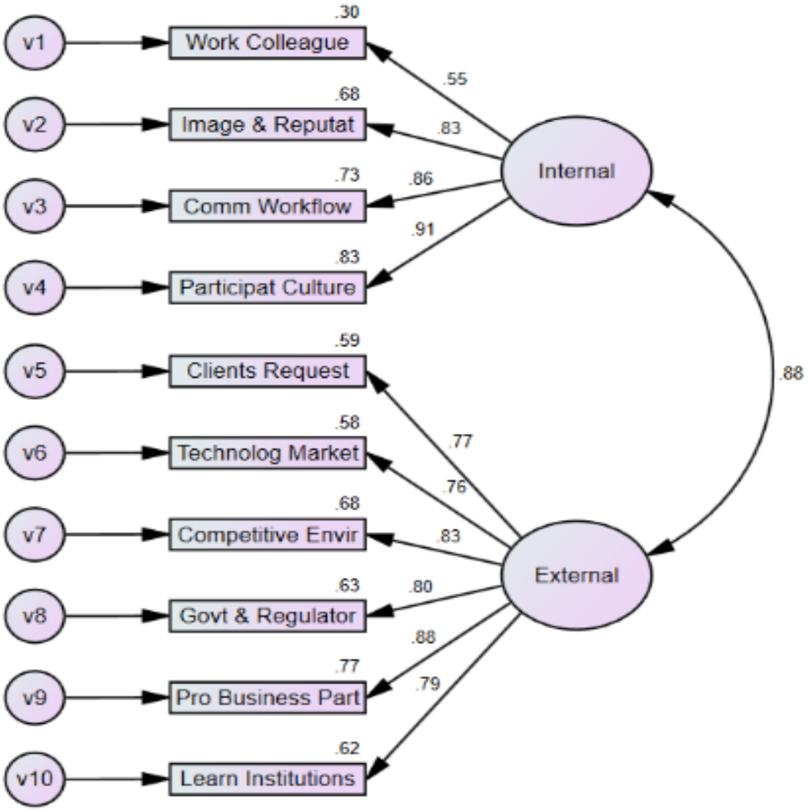
Therefore, as shown in Table 5.6, the CR of the Top Manager (.90), Digital Manager (.92), and Employee (.89) indicates that the data reliability is acceptable. Furthermore, Table 5.6 provides insight into how the constructs are captured by presenting the actual wordings of the indicators of each construct - as presented in the survey. This gives insight into the strength (strong or weak) of the relationship between the indicators and their associated construct. Accordingly, indicators with factor loadings below the recommended value of .70 contribute little to the understanding of the construct (Collier, 2020). Therefore, all indicators for the *Top Manager*, *Digital Manager* and *Employee* constructs have strong relationships values denoting that they significantly contribute to the understanding of the constructs with regards to BIM adoption within Nigerian SMAFs. They are therefore acceptable and in accordance with the reviewed extant literature.

Additionally, the t-value and probability measure how many standard deviations our coefficient estimates are from 0, while values that are further from zero indicate the relationship exists. In this regard, the highest t-value, as presented in Table 5.6, is the Top Manager's strategic knowledge of BIM, which has a regression weight of 20.08 standard errors above zero. Therefore, the probability of getting a critical ratio as large as 20.08 in absolute value is less than 0.001. In other words, the regression weight for IC_TM_3 (strategic knowledge of BIM) in the prediction of Top Manager is significantly different from zero at the 0.001 level (two-tailed). Thus, it can be declared that a relationship between the IC_TM_3 and the Top Manager construct exists. Consequently, based on the positive t-values, which are all above 0, as shown in Table 5.6, the existence of the relationship between the indicators and their associated constructs is evident.

Furthermore, from the 'Model Fit Statistic' output, it is observed that the relative chi-square fit test is just above 1.0, which means an acceptable fit is achieved. The comparative fit indices of CFI, TLI, and NFI are all above .90, further supporting the model's fit to the data. Lastly, the RMSEA value is .07, providing additional support that the model 'fits' the data. Conclusively, from this CFA, there is evidence that our indicators measure their intended concept.

5.7.3 Environmental Control Analysis

The Environmental Control (*EC*) category consists of two unobservable variables (latent constructs): Internal Pressure and External Pressure. In Figure 5.5, the *EC* model diagram shows the *Internal Pressure* (IP) construct to have four indicators (i.e. pressure from a work colleague, maintaining image & reputation, communication workflow, and participatory culture), and the *External Pressure* (EP) construct to have six indicators (i.e. pressure from client request, technology market, competitive environment, government & regulatory bodies, business partners, and educational learning institutions).



Endogenous Latent Constructs:
Internal = Internal Pressure, **External** = External Pressure

Figure 5.5: Environmental Control Estimates

Additionally, Figure 5.5 summarises the standardised estimates (factor loadings), and the correlation between the constructs and indicators. The estimates, or factor loadings, range between 0 to 1, and the closer the value to 1, the stronger the relationship between the indicator and the construct (Collier, 2020). As such, in comparing the regression weights of the indicators across the *Internal Pressure* construct, the strength of relationship from strongest to weakest are: pressure from participatory culture (.91), communication workflow (.86), maintaining image & reputation (.83), and work colleague (.55). However, with regards to the *External Pressure* construct, the strongest to the weakest indicators are: pressure from business partners (.88), competitive environment (.83), government & regulatory bodies (.80), educational learning institutions (.79), client request (.77), and technology market (.76).

Table 5.7 presents the CFA result of the Environmental Control category. This CFA result consists of the three constructs and their associated indicators, the composite reliability (CR), the standardised factor loadings, the t-value and the model fit statistics (i.e. χ2, df, p-value, CFI, TLI, NFI, RMSEA) for the *EC* construct. Furthermore, the CFA result of the *EC* constructs and describes the extent to which each indicator relates to their associated construct. Moreover, the correlations and covariance estimates are utilised to calculate and establish the EC constructs' convergent validity (6.6.1) and discriminant validity (6.6.2).

Table 5.7: Environmental Control: Confirmatory Factor and Reliability Analysis

Constructs	*Standardised Factor Loading*	*t-value*
Internal Pressure (C.R. = 0.85)		
Internal pressure from:		
○ Work colleagues – (EC_IP_1)	0.55	09.79
○ Communication workflow – (EC_IP_2)	0.83	17.16
○ Participatory culture – (EC_IP_3)	0.86	***
○ Maintaining image and reputation – (EC_IP_4)	0.91	20.27
External Pressure (C.R. = 0.92)		
External pressure from:		
○ Client knowledge and request – (EC_EP_1)	0.77	14.71
○ Technology marketplace – (EC_EP_2)	0.76	14.59
○ Environment competitiveness – (EC_EP_3)	0.83	***
○ Government and regulatory system – (EC_EP_4)	0.80	15.58
○ Professional business partner – (EC_EP_5)	0.88	18.06
○ Learning Institutions – (EC_EP_6)	0.79	15.40

Model Fit Statistics (χ_2 = 157.18, df = 34, p = 0.00; CFI = 0.94, TLI = 0.92, NFI = 0.93, RMSEA = 0.04)

C.R. = Composite Reliability

** = Items constrained for identification purposes.

Therefore, as shown in Table 5.7, the CR of Internal Pressure (.85) and External Pressure (.92) reveals that the data reliability is acceptable. Furthermore, Table 5.7 provides insight into how the constructs are captured by presenting the actual wordings of the indicators of each construct, as presented in the survey. This gives insight into the strength (strong or weak) of the relationship between the indicators and their associated construct. Accordingly, indicators with factor loadings below the recommended value of .70 contribute little to the understanding of the construct (Collier, 2020). Considering this, all indicators of the *External Pressure* construct have strong relationship values denoting that they significantly contribute to the understanding of the constructs with regards to BIM adoption within Nigerian SMAFs.

However, within the *Internal Pressure* construct, three indicators - maintaining image & reputation (.91), participatory culture (.86), and communication workflow (.83) - have a strong relationship with the construct, which indicates that they significantly contribute to the understanding of the construct. Meanwhile, pressure from a work colleague (.55) has a weak loading or relationship with the Internal Pressure construct, denoting that it contributes little to the understanding of the Internal Pressure construct with regards to BIM adoption within Nigerian SMAFs (see marked figures in Table 5.7).

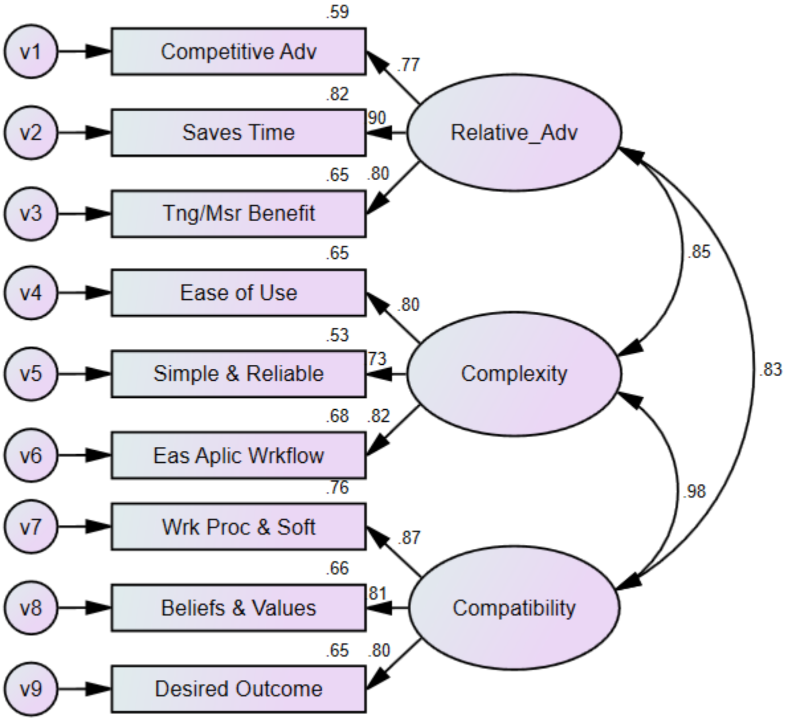
Furthermore, Collier (2020) suggests that unique indicators with weak relationships with their construct might have an effect on another construct. In the case of the indicator, Internal Pressure from work colleagues, Holzer (2015) highlighted that a potential resource during the BIM adoption process consists of interaction between management, top managers, digital managers, and employees. Therefore, the pressure from a work colleague as a result of these interactions might encourage BIM adoption within the firm (L. Ahmed & Kassem, 2018). Consequently, although the indicator (pressure from a work colleague) has a weak relationship with the Internal Pressure construct, it might influence other constructs, such as Employee, Digital Manager or Top Manager, and contribute towards understanding the relationship between these constructs and the BIM adoption process within Nigerian SMAFs. Thus, the indicator will be further investigated in the qualitative study to understand its relationship with other constructs.

Additionally, the t-value and probability measure how many standard deviations our coefficient estimates are from 0; values relatively farther from zero indicate a relationship exists. As shown in Table 5.7, the highest t-value is EC_IP_4 (maintaining image & reputation) which denotes that the probability of getting a critical ratio as large as 20.267 in an absolute value is less than 0.001. In other words, the regression weight for EC_IP_4 in predicting the *Internal Pressure* construct is significantly different from zero at the 0.001 level (two-tailed). Thus, it can be declared that a relationship between the EC_IP_4 and the *Internal Pressure* construct exists. Consequently, based on the positive t-values, which are all above 0 as shown in Table 5.7, the relationship between the indicators and their associated constructs is evident.

Furthermore, from the 'Model Fit Statistic' output, it is observed that the relative chi-square fit test is just above 1.0, which means an acceptable fit is achieved. The comparative fit indices of CFI, TLI, and NFI are all above .90, further supporting the model's fit to the data. Lastly, the RMSEA value is .04, providing additional support that the model 'fits' the data. Conclusively, from this CFA, there is statistical evidence that our indicators measure their intended concept except for one indicator (EC_IP_1).

5.7.4 Technological Quality Analysis

The Technology Quality (*TQ*) category consists of three latent constructs (unobservable variables) as shown in the *TQ* model diagram in Figure 5.6. These three *TQ* constructs are: Relative Advantage (three indicators: competitive advantage, saves time, tangible measurable benefit), Complexity (three indicators: complexity with regards to ease of use, simplicity & reliability, applicability to workflow), and Compatibility (three indicators: Compatibility with work process and other software, beliefs & values, and desired outcome).



Endogenous Latent Constructs:
Relative_Adv = Relative Advantage, **Complexity** = Complexity, **Compatibility** = Compatibility

Figure 5.6: Technology Quality Estimates

Furthermore, Figure 5.6 summarises the standardised estimates (factor loadings), and the correlation between the constructs and indicators within the *TQ* Category. The estimates or factor loadings range between 0 to 1. The closer the value to 1, the greater the indicator's strength on the construct (Collier, 2020). As such, comparing the regression weights of the indicators across the Relative Advantage (RA) construct, the strength of relationship from strongest to weakest are as follows: saves time (.90), tangible, measurable benefit (.80), and competitive advantage (.77).

However, with regards to the Complexity (CX) constructs, the strongest to the weakest indicators are: applicability to the workflow (.82), ease of use (.80), and simplicity & reliability (.73). Similarly, the estimates of the Compatibility (CT) construct revealed the strongest to weakest indicators to be: Compatibility with work process and other software (.87), beliefs & values (.81), and desired outcome (.80).

Consequently,

Table 5.8 presents the CFA result of the Technology Quality category. This CFA result consists of the three constructs and their associated indicators, the composite reliability (CR), the standardised factor loadings, the t-value and model fit statistics (i.e. χ_2, df, p-value, CFI, TLI, NFI, RMSEA). Furthermore, the CFA result of the TQ constructs in order to describe the extent to which each indicator relates to their associated construct, while the correlations and covariance estimates are utilised to calculate and establish the convergent validity (6.6.1) and discriminant validity (6.6.2) of the *TQ* constructs.

Table 5.8: Technological Quality: Confirmatory Factor and Reliability Analysis

Constructs	*Standardised Factor Loading*	*t-value*
Relative Advantage (C.R. = 0.86) BIM technology provides our firm with:		
○ Competitive advantage – (TQ_RA_1)	0.77	13.86
○ Tangible, measurable benefits – (TQ_RA_2)	0.90	16.74
○ saves us time during project design and delivery – (TQ_RA_3)	0.80	***
Complexity (C.R. = 0.82) BIM technology is:		
○ Easily applicable to our workflow – (TQ_CX_1)	0.80	15.56
○ Simple and reliable – (TQ_CX_2)	0.73	13.48
○ Easy to use – (TQ_CX_3)	0.82	***
Compatibility (C.R. = 0.87) BIM technology is compatible with our:		
○ Current work practices – (TQ_CT_1)	0.87	
○ Believes and values – (TQ_CT_2)	0.81	16.77
○ Desired outcomes – (TQ_CT_3)	0.80	15.34

Constructs	*Standardised Factor Loading*	*t-value*
		***

Model Fit Statistics (χ_2 = 202.03, df = 24, p = 0.00; CFI = 0.91, TLI = 0.96, NFI = 0.98, RMSEA = 0.06)
C.R. = Composite Reliability
** = Items constrained for identification purposes.

Therefore, as presented in

Table 5.8, the CRs for Relative Advantage (.86), Complexity (.82), and Compatibility (.87) show that the data reliability is acceptable. Furthermore,

Table 5.8 provides insight into how the constructs are captured by presenting the actual wordings of the indicators of each construct, as presented in the survey. This gives an insight as to which indicators have strong or weak relationships with their associated construct. Accordingly, indicators with factor loadings below the recommended value of .70 contribute little to the understanding of the construct (Collier, 2020). Considering this, all indicators for the *Relative Advantage*, *Complexity*, and *Compatibility* constructs have strong relationship values denoting that they significantly contribute to the understanding of the constructs with regards to BIM adoption within Nigerian SMAFs. They are therefore acceptable and in accordance with the reviewed extant literature.

Additionally, the t-value and probability measure how many standard deviations our coefficient estimates are from 0, and values further from zero indicate a relationship exists. In this regard, the highest t-value, as presented in

Table 5.8, is the Top Manager's strategic knowledge of BIM, which has a regression weight of 16.77 standard errors above zero. Therefore, the probability of getting a critical ratio as large as 20.08 in absolute value is less than 0.001. In other words, the regression weight for TQ_CT_1 (current work practice) in the prediction of the *Compatibility* construct is significantly different from zero at the 0.001 level (two-tailed). Thus, it can be declared that a relationship between the TQ_CT_1 and the Top Manager construct exists. Consequently, based on the positive t-values, which are all above 0, as shown in

Table 5.8, the existence of the relationship between the indicators and their associated constructs is evident.

Furthermore, from the ‘Model Fit Statistic’ output, it is observed that the relative chi-square fit test is just above 1.0, which means an acceptable fit is achieved. The comparative fit indices of CFI, TLI, and NFI are all above .90, further supporting the model’s fit to the data. Lastly, the RMSEA value is .06, providing additional support that the model ‘fits’ the data. Conclusively, from this CFA, there is evidence that our indicators are measuring their intended concept.

5.8 Validity Measurement

Assessing the validity measurement is the next step after establishing that the model has an acceptable fit to the data and that each indicator is loaded onto its corresponding construct. According to Collier (2020), convergent validity examines if indicators will converge to assess a single notion. In contrast, discriminant validity examines whether a construct is unrelated or distinct from other conceptions. Furthermore, Collier (2020) stated that although CFA is an excellent initial step towards determining validity, the result from CFA alone is insufficient to confirm convergent and discriminant validity. Therefore, Fornell & Larcker’s (1981) framework is an excellent framework for examining this type of validity and is still utilised by many academics today. In the subsequent sections, the convergent validity and the discriminant validity will be presented, respectively.

5.8.1 Convergent Validity Measure

Fornell and Larcker (1981) recommend calculating the Average Variance Extracted (AVE) for each construct to determine the convergent validity. The R^2 value for each indicator in a construct is added together and divided by the total number of indicators to calculate the AVE. For indicators to have convergent validity on your construct, the AVE value must be more than .50. Considering this, the subsequent sections present the calculations for the AVE of the constructs used in the CFA.

5.8.1.1 Organisational Capability Validity Measure

The convergent validity of the *OC construct,* including Management Support, IT Infrastructure and Process and Policy, are highlighted in Table 5.9. Furthermore, Table 5.9 reveals the AVE of Management Support as 0.64, IT Infrastructure as 0.88, and Process and Policy as 0.87. Considering that the AVE for each *OC construct* has a value greater than 0.5, this provides evidence of convergent validity for the indicators of each unobserved variable. In other words, all the indicators 'converge' when measuring their associated construct.

Table 5.9: Organisational Capability Average Variance

Management Support R^2	IT Infrastructure R^2	Process and Policy R^2
OC_MS_1 = 0.43 OC_MS_2 = 0.99 OC_MS_3 = 0.53 OC_MS_4 = 0.79 OC_MS_5 = 0.48	OC_II_1 = 0.88 OC_II_2 = 0.90 OC_II_3 = 0.89 OC_II_4 = 0.86	OC_PP_1 = 0.87 OC_PP_1 = 0.94 OC_PP_1 = 0.81
AVE = 0.64	**AVE = 0.88**	**AVE = 0.87**

5.8.1.2 Individual Competence Validity Measure

The IC construct's convergent validity, including the Top Manager, Digital Manager, and Employee, are highlighted in Table 5.10. Furthermore, Table 5.10 revealed the AVE of the Top Manager as 0.74, the Digital Manager as 0.74, and the Employee as 0.68. As the AVE for each IC construct has a value greater than 0.5, this offers evidence of convergent validity for the indicators of each unobserved variable. In other words, all indicators measure their associated constructs.

Table 5.10: Individual Competence Average Variance

Top Manager R^2	Digital Manager R^2	Employee R^2
IC_TM_1 = 0.69 IC_TM_2 = 0.76 IC_TM_3 = 0.78	IC_DM_1 = 0.76 IC_DM_2 = 0.73 IC_DM_3 = 0.69 IC_DM_4 = 0.78	IC_E_1 = 0.57 IC_E_1 = 0.71 IC_E_1 = 0.74 IC_E_1 = 0.71
AVE = 0.74	**AVE = 0.74**	**AVE = 0.68**

5.8.1.3 Environmental Control Validity Measure

The EC constructs convergent validity, including Internal Pressure and External Pressure, are highlighted in Table 5.11. Furthermore, Table 5.11 revealed the AVE for Internal Pressure as 0.64 and External Pressure as 0.65. As the AVE for each EC construct has a value greater than 0.5, this supports the convergent validity for the indicators of each unobserved variable. In other words, all indicators measure their intended constructs.

Table 5.11: Environmental Control Average Variance

Internal Pressure R^2	External Pressure R^2	
EC_IP_1 = 0.30	EC_EP_1 = 0.59	EC_EP_5 = 0.77
EC_IP_2 = 0.68	EC_EP_2 = 0.58	EC_EP_6 = 0.62
EC_IP_3 = 0.73	EC_EP_3 = 0.68	
EC_IP_4 = 0.83	EC_EP_4 = 0.63	
AVE = 0.64	**AVE = 0.65**	

5.8.1.4 Technological Quality Validity Measure

The convergent validity of the *TQ constructs,* including the Relative Advantage, Complexity and Compatibility, are highlighted in Table 5.12. Furthermore, Table 5.12 revealed the AVE for Relative Advantage as 0.69, Complexity as 0.62, and Compatibility as 0.69. As the AVE for each *TQ construct* has a value greater than 0.5, this supports the convergent validity for the indicators of each unobserved variable. In other words, all indicators measure their intended constructs.

Table 5.12: Technological Quality Average Variance

Relative Advantage R^2	Complexity R^2	Compatibility R^2
TQ_RA_1 = 0.59	TQ_CX_1 = 0.65	TQ_CT_1 = 0.76
TQ_RA_2 = 0.82	TQ_CX_2 = 0.53	TQ_CT_2 = 0.66
TQ_RA_3 = 0.65	TQ_CX_3 = 0.68	TQ_CT_3 = 0.65
AVE = 0.69	**AVE = 0.62**	**AVE = 0.69**

5.8.2 Discriminant Validity Measures

Campbell and Fiske (1959) developed the notion of discriminant validity while discussing test validity evaluation and stressed the significance of employing both discriminant and convergent validation techniques when evaluating a model. This is because convergent validity measures determine if all the indicators for a construct measure the 'same' thing. In contrast, discriminant validity determines if the constructs within a category measure different things. In this regard, all relationships between the variables within the model are validated. As mentioned in section 6.6, discriminant validity reflects the extent to which the constructs of the model differ, determining whether the constructs measure different concepts. Therefore, to evaluate the discriminant validity of the model, each correlation is investigated through a comparison between the shared variance to AVE (Collier, 2020; Holmes-Smith, Cunningham & Coote, 2006). However, to establish the shared variance of each construct, the correlations squared are compared to the AVE values (Collier, 2020). Thus, when the AVE value exceeds the shared value of the constructs, it indicates that the model is discriminately valid, which implies that the constructs measure different concepts (Collier, 2020). Accordingly, the discriminant validity measure of the model is evaluated in the subsequent sections.

5.8.2.1 Organisational Capability Measure

To examine the discriminant validity of the *OC*, the shared variance between each construct (i.e. Support, Infrastructure, Process) was determined by comparing the square of the correlation and the AVE values of each construct. Table 5.13 shows the *OC* correlation and the square of the correlation for each construct.

Table 5.13: Organisational Capability Correlation

Correlation between Constructs			Estimates	$(\text{Correlation})^2$
Support	<-->	Infrastru	0.49	$(0.49)^2 = 0.24$
Process	<-->	Infrastru	0.92	$(0.92)^2 = 0.84$
Process	<-->	Support	0.54	$(0.54)^2 = 0.29$

Management Support and IT Infrastructure's shared variance is 0.24, which is significantly lower than the AVE for Management Support (0.64) or IT Infrastructure (0.88). As a result, there is evidence that these notions are discriminatory towards one another. Similarly, the shared variance of Process and Policy and IT Infrastructure is 0.84, which is smaller than the AVE value for both Process and Policy (0.87) and IT Infrastructure (0.88). Also, the shared variance of Process and Infrastructure is 0.29, which is far lower than the AVE for Process (0.87) or Management Support (0.64). This means that there is evidence that these notions are discriminatory towards one another. Considering that all AVE values exceed the shared variance between the constructs, this confirms that the constructs in the model support the discriminant validity. In other words, all three constructs within the OC category measure different concepts.

5.8.2.2 Individual Competence Measure

To examine the discriminant validity of the *IC*, the shared variance between each construct (i.e. Top Manager, Digital Manager and Employee) was determined by comparing the square of the correlation and the AVE values of each construct. As a result, Table 5.14 shows the *IC* correlation and the square of the correlation for each construct.

Table 5.14: Individual Competence Correlation

Correlation between Constructs			Estimates	(Correlation)^2
Top_Manager	<-->	Digital_Manager	0.87	$(0.87)^2 = 0.76$
Employee	<-->	Digital_Manager	0.83	$(0.84)^2 = 0.71$
Employee	<-->	Top_Manager	0.87	$(0.87)^2 = 0.76$

The shared variance of Top Manager and Digital Manager is 0.76, which is slightly higher than the AVE for Top Manager (0.74) or Digital Manager (0.74). As a result, there is evidence that these notions are not discriminatory towards one another. This means that the Top Manager and Digital Manager constructs are highly related to one another. Similarly, the Employee and Digital Manager's shared variance is 0.71, which is also higher than the AVE value for Employee (0.68) and lower than the AVE value for Digital Manager (0.74). This signifies that the Employee and Digital Manager constructs are not discriminatory towards one another, indicating that both constructs are highly related to each other.

Similarly, the Employee and Top Manager's shared variance is 0.76, which is higher than the AVE for Employee (0.68) and Top Manager (0.74). This means that there is evidence that these notions are also not discriminatory towards one another and are highly related to each other. Considering that all discriminate measures indicate that the constructs are highly related, this denotes that the factors that influence one construct regarding BIM adoption within Nigerian SMAFS might also influence the other constructs. Thus, except for Digital Manager, there is a significant similarity in the concept measured by the Top Manager and Employee constructs.

5.8.2.3 Environmental Control Measure

To examine the discriminant validity of the *EC*, the shared variance between each construct (i.e. Internal and External Pressure) was determined by comparing the square of the correlation and the AVE values of each construct. Table 5.15 presents the *EC* correlation and the square of the correlation for each construct.

Table 5.15: Environmental Control Correlation

Correlation between Constructs			Estimates	(Correlation)^2
Internal	<-->	External	0.88	$(0.88)^2 = 0.77$

Furthermore, this shows that the shared variance of Internal Pressure and External Pressure is 0.77, which is higher than the AVE for Internal Pressure (0.64) or External Pressure (0.65). Therefore, the construct of the model does not support the discriminant validity since the AVE value did not exceed the shared variance between the constructs (i.e. Internal Pressure and External Pressure). This means that internal and external constructs are related to each other.

5.8.2.4 Technological Quality Measure

To examine the discriminant validity of the *TQ*, the shared variance between each construct (i.e. Compatibility, Complexity, Relative Advantage) was determined through comparing the square of the correlation and the AVE values of each construct. Thus, Table 5.16 shows the *TQ* correlation and the square of the correlation for each construct.

Table 5.16: Technological Quality Correlation

Correlation between Constructs			Estimates	$(\text{Correlation})^2$
Compatibility	<-->	Complexity	0.85	$(0.85)^2 = 0.72$
Relative_adv	<-->	Complexity	0.98	$(0.98)^2 = 0.96$
Relative_adv	<-->	Compatibility	0.83	$(0.83)^2 = 0.68$

The shared variance of Compatibility and Complexity is 0.72, which is higher than the AVE for Compatibility (0.69) or Complexity (0.62). As a result, there is evidence that these notions are not discriminatory towards one another. Similarly, Relative Advantage and Complexity's shared variance is 0.96, which is higher than the AVE value of both Relative Advantage (0.69) and Complexity (0.69). Also, Relative Advantage and Compatibility's shared variance is 0.68, which is far lower than the AVE for Relative Advantage (0.69) or Compatibility (0.69). This means that there is evidence that these notions are discriminatory towards one another. Considering this, only the AVE value of Relative Advantage and Compatibility exceeds the shared variance between the constructs, which confirms that the constructs in the model partially support the discriminant validity. This means that 'Compatibility and Complexity' as well as 'Relative Advantage and Complexity' are related to each other with regards to the concept they measure (i.e. the influence of technology quality on BIM adoption within Nigerian SMAFs), while Relative Advantage and Compatibility are not related to each other, although they are within the same TQ category

In summary, the discriminant validity measures whether two constructs are empirically distinct. Although 11 constructs were measured for discriminant validity, the distinct constructs comprise three from the OC category (Support and Infrastructure, Process and Infrastructure, Process and Support) and one from the TQ category (Relative Advantage and Compatibility). In contrast, the highly related constructs in terms of the concept they measure comprised three from the IC category (Top Manager and Digital Manager, Employee and Digital Manager, and Employee and Top Manager), one from the EC category (Internal and External Pressure), and two from the TQ category (Compatibility and Complexity, Relative Advantage and Complexity). Overall, this means that some of the constructs are similar with regards to the concept they measure despite theoretical evidence that they are distinct. In addition, this indicates that the factors within the conceptual model are valid, and these would contribute to the development of the framework that aims to understand BIM adoption within Nigerian SMAFs. Nonetheless, these ambiguities will be further evaluated through a qualitative study in the next chapter. Consequently, the validated conceptual model will be used to evaluate the relationships between the factors influencing BIM adoption and the process of BIM adoption within Nigerian SMAFs.

5.9 Chapter Summary

This chapter reports the quantitative results with the primary objective of critically investigating the relevance of the factors to the conceptual model. A pilot study was conducted, which yielded 40 responses. The pilot study was analysed and tested and was found to have excellent reliability. However, feedback from the pilot study helped in adjusting the questionnaire for the main study. Subsequently, the preliminary data analysis was presented based on the responses from the main questionnaire survey. This preliminary data analysis evaluated the background of the survey respondents, which confirmed that the intended target population (i.e. Nigerian SMAFs) was accurately captured. Additionally, the reliability test for the constructs was found to be very good. Considering this, the model measurement analysis was conducted through a structural equation modelling technique. This facilitated the confirmatory factor analysis of the model variables (i.e. constructs, indicators), which established empirical evidence that supported the conceptual model and estimated the constructs within the model. The estimation process evaluated the model's fit and fit statistics to investigate how well the variables (constructs and indicators) fit the model. Subsequently, the validity measurement (i.e. convergence validity and discriminant validity) were estimated. Although the model's convergent validity and discriminant validity were acceptable overall, some constructs need to be investigated further because some discriminant validities were found to be insufficiently different. Thus, as presented in the next chapter, a qualitative study was conducted to explore the relationship between the indicators (i.e. factors) and the BIM adoption process within Nigerian SMAFs.

6 Chapter Six – Qualitative Study

6.1 Chapter Overview

The last chapter presented the analysis, finding and discussion of the quantitative data through utilising the concept of structural equation modelling to validate the model fitness and hypothesis of the research model. The purpose of this chapter is to present and synthesize the empirical findings from the qualitative study based on semi-structured interviews. Accordingly, this chapter is structured as follows:

- Background of interview participants according to their roles, the size and structure of the firms they represent, the BIM levels and tools utilised.
- Overview of the current BIM Status within the Nigerian small and medium architectural firms (SMAFs). This elaborates on the current understanding of BIM, the motivation, benefits and challenges of BIM adoption within the Nigerian SMAFs.
- Analysis of the superordinate and subordinate themes of BIM within the SMAFs that emerged from the data/interview verbatim transcripts. The superordinate themes include organisational capability, environmental control, individual competence, and technological quality.
- Discussion of the themes and their influence on BIM adoption within the Nigerian SMAFs based on the interviews.

The chapter summary is presented at the end. These are discussed accordingly.

6.2 Interview Thematic Analysis

The questions of the interview were structured to be versatile enough to extract the relevant information from the participants' experience in their various firms. Although the questions were based on the result ascertained from the literature review and questionnaire survey, the flexibility of the interview questions allowed themes and trends to emerge. Considering this, the qualitative data were analysed using a thematic analysis after the interview was transcribed. As a result, superordinate themes in conjunction with a number of associated subordinate themes were derived from the results. Furthermore, the superordinate and subordinate themes will be analysed alongside the verbatim quotes from the transcript to support the discussions in the subsequent sections. Additionally, the interviewees from which the quotations were taken is denoted by the code **P** (followed by a number between 1 to 17) as shown in Table 6.1 in order to main anonymity as mentioned in the participant information sheet (See Appendix 6).

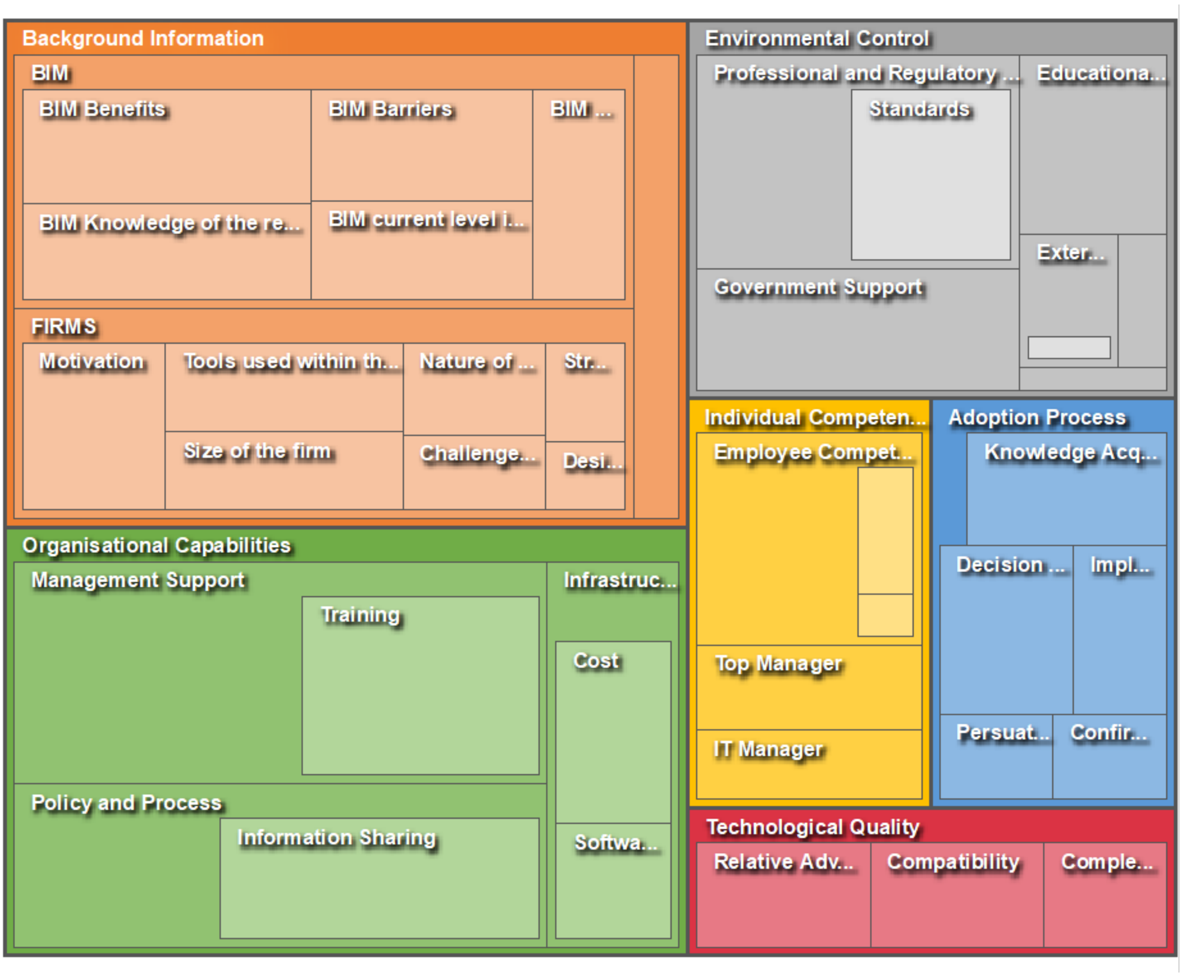


Figure 6.1: Summary of themes

Figure 6.1 shows the summary of the themes that emerged from the thematic analysis using NVivo 12. Furthermore, the six (6) colour coded categories are further classified the following sections:

- The background information of the participants
- The current BIM status in the Nigeria SMAFs
- The BIM adoption process in the Nigerian SMAFs
- The analysis of the superordinate themes i.e. organisational capability, environmental control, individual competence, and technological quality.

These sections reflect the questions asked in the interview and are identified based on the purpose of the study. In this section, verbatim quotations extracted from the transcription of the interview are used to support the assertions.

6.2.1 Background of Interview Participants

To achieve the purpose of in-depth exploration, seventeen (17) semi-structured interviews were conducted. The interviews aim to examine the factors that influence BIM adoption within Nigerian small and medium architectural firms (SMAFs). However, participant information captured during the interview such as position or job role, firm size, BIM level and tools, were deemed necessary for two reasons. The first reason is to verify that the firm characteristics such as firm size are within the scope of the study, which is Nigerian SMAFs. Secondly, is to understand how these characteristics influence and motivate the process of BIM adoption within the Nigerian SMAFs. Furthermore, the interview participants were labelled P01, P02 … P17 in accordance with ethical considerations of the use of anonymous quotes.

Table 6.1, presents a summary of sampled participants of the semi-structured interviews providing details of the interviewee's background, position, firm size, BIM level and BIM tool.

Table 6.1: Summary of interview participant information

S/No	Code	Position	Firm size (FS)	BIM level (BL)	BIM tools
P01	Alpha	Head of Unit	51 - 250 Staff – Medium	Level 2: Collaboration	Revit
P02	Bravo	Designer & Supervisor	10 - 50 Staff – Small	Level 0: CAD	AutoCAD only
P03	Charlie	Project Manager	10 - 50 Staff – Small	Level 1: Model	ArchiCAD, AutoCAD, Revit
P04	Delta	CEO	< 10 Staff – Micro	Level 2: Collaboration	ArchiCAD, Lumion, Navisworks, Revit, Sketchup, BIM 360, 3Ds
P05	Echo	Site Supervisor	51 - 250 Staff – Medium	Level 1: Model	AutoCAD, Revit, Sketchup
P06	Foxtrot	Head of Planning Unit	51 - 250 Staff – Medium	Level 2: Collaboration	ArchiCAD, AutoCAD, Lumion, Navisworks, Sketchup
P07	Golf	CEO	10 - 50 Staff – Small	Level 1: Model	ArchiCAD, Revit
P08	Hotel	Designer	< 10 Staff – Micro	Level 1: Model	AutoCAD, Revit
P09	India	Designer & Supervisor	10 - 50 Staff – Small	Level 1: Model	AutoCAD, Revit, Sketchup
P10	Juliet	Project Manager	51 - 250 Staff – Medium	Level 1: Model	AutoCAD, ArchiCAD, Lumion

P11	Kilo	Owner	< 10 Staff – Micro	Level 2: Collaboration	AutoCAD, ArchiCAD, Lumion, Navisworks, Revit, BIM 360
P12	Lima	Site Supervisor	10 - 50 Staff – Small	Level 1: Model	ArchiCAD, Revit
P13	Mike	Project Manager	51 - 250 Staff – Medium	Level 1: Model	Lumion, Navisworks, Revit
P14	November	Project Manager	< 10 Staff – Micro	Level 1: Model	ArchiCAD, Revit
P15	Oscar	Site Supervisor	10 - 50 Staff – Small	Level 1: Model	AutoCAD, ArchiCAD
P16	Papa	Designer & Supervisor	< 10 Staff – Micro	Level 1: Model	AutoCAD, ArchiCAD, Revit,
P17	Quebec	Designer Supervisor	10 - 50 Staff – Small	Level 1: Model	ArchiCAD, Revit, Sketchup

6.2.1.1 Participants Positions

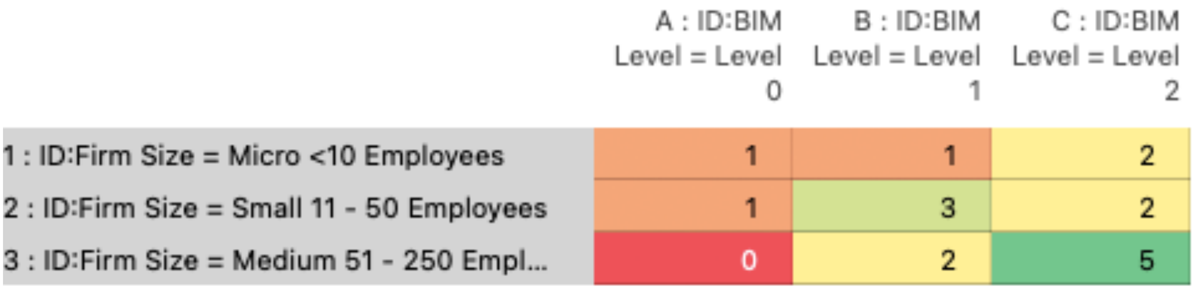
The participants of the interview are all architects with different positions and job roles as shown in Table 6.1. The interview participant roles were categorised into CEO (including owners and head of units), managers, designers, and supervisors (including site and design supervisors). The distribution of interviewees based on their positions are CEOs (29.4%), managers (23.5%), supervisors (41.2%) and designers (29.4%). The views of professionals across the four (4) categories are synthesised with their respective firm size and BIM level to confirm that it is within the research context, which is BIM adoption within the SMAFs (i.e. it is important to understand the size of the firm and the level of BIM usage in order to confirm that it is within the research context).

6.2.1.2 Size of the firms

The study's scope is limited to small and medium-sized firms, which are typically defined by the number of employees. As reported previously in the literature (see section 1.5), small firms are organisations with number of employees that are below 50 and medium firms with number of employees between 51 to 250. In the context of this research, Table 6.1 shows the distribution of the firm sizes the interview participants represent. In line with this statement, five (5) participants (P04, P08, P11, P14 and P16 12) disclosed the number of employees within their firms to be below ten (10), which is considered micro firms, seven (7) participants (P2, P3, P7, P9, P12, and P17) disclosed the number of employees within their firms to be between ten to fifty (10 – 50), which is considered small firms, while the remainder five (5) participants (P1, P5, P6, P10 and P13) participants disclosed the number of employees in their firm to be between fifty-one and two hundred (51 – 250), which is considered to be a medium firm. Nonetheless, the sizes of the interviewee's firms are all small and medium and are therefore within the scope of the study.

6.2.1.3 Current Level of BIM Maturity

As shown in Table 6.1, the level of BIM maturity indicated by interview participants is divided into three (3) categories: level 0 (CAD), level 1 (model), and level 2 (collaboration).The distribution of the firms that are on the BIM levels are, one (1) participant (P02) associated with level 0 (5.9%), twelve (12) participants are associated with BIM level 1 (70.6%) and four (4) participants (P1, P4, P6 and P11) are associated with BIM level 2 (23.5%). However, only three (3) of the interviewee participants ever participated in a project where BIM is deployed (P01). This can be seen as an evident lack of understanding and participation (BIM adoption) by professionals in collaborative working (P11). However, since only three participants disclosed that they have participated in a BIM deployed project, it shows that the other thirteen participants with BIM maturity levels one and two are likely practicing a 'lonely BIM' at the modelling and collaboration stage.



	A : ID:BIM Level = Level 0	B : ID:BIM Level = Level 1	C : ID:BIM Level = Level 2
1 : ID:Firm Size = Micro <10 Employees	1	1	2
2 : ID:Firm Size = Small 11 - 50 Employees	1	3	2
3 : ID:Firm Size = Medium 51 - 250 Empl...	0	2	5

Figure 6.2: Showing matrix between Firm Size (FS) vs BIM Level (BL)

The distribution of firm size (FS) and their respective level of BIM maturity (BL) can be seen in Figure 6.2, from the matrices between FS and BL. For the micro firms, one (1) participant is associated with BIM level 0, one (1) participant is associated with BIM level 1 and two (2) participants are associated with BIM level 2. Similarly, from small firms, one (1) participant is associated with BIM level 0, three (3) participants are associated with BIM level 1 and two (2) participants are associated with BIM level 2. Additionally, this shows that there are no participants associated with BIM level 0, two (2) participants are associated with BIM level 1 and five (5) participants are associated with BIM level 2 from the medium firm.

Therefore, there is indication of partial BIM implementation within the firms. Additionally, P01 stated that BIM has been implemented at the design stage and currently striving towards fully implementing BIM at other stages such as construction. This means that BIM is identified as collaborative process that involves different departments at various project phases (i.e. design, construction, maintenance).

> "Yes, I would say partially, I will not say that we implement BIM fully but we're striving towards full BIM implementation but currently we are implementing it partially, by partially I mean on the design side yes, we are definitely using just about every aspect of it but during the construction phase of the project when it involves different departments, I don't think the project development department are using BIM holistically. We have achieved 80 to 90% of BIM implementation at the design stage, and I think that is why it is partially sorted out on that side already. – P01"

Furthermore, P04 disclosed that BIM software is utilised only to certain extent because of the limitation that arises from their professional business partners that are not familiar with BIM tools. This also affirm that BIM is understood to involve other professional business partners and therefore the professional business partners such as engineers inadequate BIM knowledge affects the full implementation of BIM within the SMAFs.

> "In our own case, what we do is we normally use software like Revit, Lumion and a bit of AutoCAD for our partners that don't know how to use this building information modelling software. – P04"

Nonetheless, interview participant such as P11 mentioned that although their firm is yet to adopt a BIM process because the firm is relatively new, they are gradually working towards the adoption. Furthermore, although there is a lot of encouragement towards adopting BIM within the SMAFs, the adoption process is understood to be a gradual process. This indicates that there is a strategy of adopting BIM gradually within the SMAFs especially those at BIM level 2 maturity.

> "not yet we are in the process of adopting it gradually. Hopefully, we have started but not fully integrated. At the moment since it is relatively new to the company just a few people are using it, but we are encouraging others that are not using it to use it. – P11"

This section introduced the interviewee participants, their job positions, the category of firms they represent and the firm's level of BIM and tools utilised. The next section presents findings on the current BIM adoption status as elicited from the interview participants.

6.2.1.4 Current Available BIM Tools

From the summary of the interview participant information in Table 6.1, there is an indication that firms use only a select few BIM tools within their organisations and not in collaboration with other firms, i.e., lonely BIM. On the other hand, 'Big BIM', as it has been referred to (i.e. in collaboration with other organisations), is mostly happening with highly developed firms with BIM maturity level 2, who have revealed that they have been practicing collaborative design at the organizational level. However, there is still traces of firms that are using the traditional way to deliver projects, as P02 highlighted. For example, firms with BIM maturity level of 0 utilise 2D tools such as AutoCAD to deliver their project designs while outsourcing the 3D designs to other firms that utilise 3D software such as ArchiCAD and Revit. This means that although, BIM maturity level 0 firms are limited to 2D CAD tools, the need for 3D visualisation in their workflow is acknowledged and hence outsourcing the 3D services to other firms with higher BIM maturity.

> "No, we are using the old way. I mean mostly the majority uses AutoCAD. Yes, they are in 2D because those people that you find using Revit are those that are doing 3D for you. once you give them in AutoCAD, I think they converted it to Revit and produce the 3D. – P02".

Furthermore, upon deeper conversation with some of the firms, it was apparent that the same BIM tools can be utilised for different purposes. For example, *P16 and P03* have BIM maturity level 1, P16 utilises ArchiCAD for all the design activities i.e., for producing working drawings, presentation drawings, plans, elevations, section designs and 3D visualisation while P03 utilises AutoCAD for drafting only and Revit or ArchiCAD for visualisation and 3D modelling only.

> "Like in working drawings and presentation drawings for plans and elevations and the sections most of the times we use ArchiCAD. Well for the 3DS we use the ArchiCAD sometimes. – P16"
>
> "Yes, we use the well-known Revit for design and other related activities, and we use ArchiCAD and AutoCAD as well for drafting – P03".

Similarly, firms with BIM maturity level 2 such as *P11* utilise similar BIM tools such as Revit from concept design through to the construction stage unlike BIM maturity level 1 firms that only utilise the BIM tools within design phase only. However, the two major BIM tools that the interviewees used for design delivery are Revit and ArchiCAD. Other notable tools highlighted are Lumion and SketchUp for visualisation, Navisworks and Synchro for 4D coordination.

> "… Revit, Lumion and a bit of AutoCAD. I think since we are using Revit, ArchiCAD and sometimes SketchUp, I can say we do use building information modelling tools in our own firm but maybe not extensively to a certain limit. – P11"

Accordingly, P05 stated that, some professionals are unfamiliar with BIM tools such as Revit. Therefore, the choice of BIM tool use is influenced by the type of tools their professional business partners use.

> "… we use Revit for our architectural drawings, but most of the structural guys are not familiar with Revit. […] the M&E are not familiar with Revit. – P05"

Similarly, P06 stated that the main reason their firm use of AutoCAD, a 2D drafting and design tool, is that when sharing design outside of the firms, the professional partners such as engineers request 2D converted files. Therefore, there is indication that BIM is essential to sharing information and coordination of designs between professionals such as architects, mechanical and electrical engineers. Furthermore, for effective BIM adoption within the Nigerian SMAFs, there is need to consider the process of design information exchange with other professionals such as engineers.

> "we use 3D software like the Revit architecture or ArchiCAD and sometimes we use AutoCAD because every drawing end up being converted to 2D drawing when sharing with the engineers. – P06"

6.2.2 Current BIM Status in Nigerian SMAFs

In this section, the current state of BIM adoption status will be explored through the perspectives of the interviewee. This would be achieved under three main headings: the current understanding of BIM, the motivation for adopting BIM, and the challenges for adopting BIM within Nigerian SMAFs.

6.2.2.1 Current Understanding of BIM

The knowledge of BIM and understanding within the Nigerian SMAFs can be categorised into three. Firstly, the practitioners acknowledged to have a good understanding of BIM and defined BIM as a holistic approach to design, construction, and maintenance of project. Second category acknowledged not to have an understanding of BIM while the third category claimed to understand BIM but upon further disclosure, they defined BIM as a design tool only with no associated process. For example, P01 defined BIM as a holistic approach to design and construction with emphasis on embedding information in the process. This shows that BIM is a process that enables managing information during design and construction.

> “I see BIM as a holistic approach to design and construction with full information embedded in most of the processes. - P01”

Contrary to that, P09 and P14 defined BIM as simply a digital tool (CAD) used in delivering projects. Although both firms are at BIM maturity level 1, there is indication that some of the firms understand BIM to be a digital tool without the any associated process. Moreover, BIM tools such as Revit as discussed earlier to be used for rudimentary purposes only (see section 6.2.1.4). Therefore, lack of fully utilising and understanding BIM tools such as Revit might have contributed to understanding BIM to be digital tools only.

> “… It's like a design software, CAD software. – P09” “… BIM is more of a digital tool within the construction for modelling of projects. – P14”

Nonetheless, there has been evidence of efforts from practitioners to increase BIM awareness within the industry through seminars to encourage BIM usage, as P13 mentioned below. This indicates effort towards increasing BIM awareness within the Nigerian SMAFs.

> “Yes, I have because I have been to a few seminars about building information modelling, and they're trying to encourage it and introduce it to architects and engineers and construction management anyway it's about digital construction or something like that. – P13.”

Upon further enquiry, P06 portrayed BIM as a collaborative workflow process that provides a single synchronised data source between architects and engineers during the delivery of projects. Furthermore, the concept of big BIM can be identified where collaboration of SMAFs and other firms such as mechanical, electrical, and structural engineering exist. Similarly, unlike the previous paragraph, BIM is perceived to go beyond just a technology but also a process of collaboration and synchronisation of design information to enhance the workflow of information sharing during construction projects and mitigate or pre-identify possible design and construction problems such as clashes between elements (i.e. pipes, electrical wiring and columns). In a way, among the BIM benefits identified include coordination of design information, enhanced collaboration between architects and engineers, and effective project delivery workflow.

> “Basically, all are drawings and designs are done with a computer and to have a synchronised data for a building or information of a building because you have the architects work the engineers work you are and within the engineers you have the structural engineers, mechanical engineers and electrical […] So instead of having different versions of the drawing and having some clash or discrepancy during construction when you use BIM, you're going to have a synchronised drawing and it's going to have a smooth flow during construction

> you don't have columns clashing with pipes or some electrical wires doing any of that interruption – P06."

The current understanding of BIM within the Nigerian SMAF ranges from BIM as only a digital tool to BIM as collaborative process to manage information and enhance project deliver. Although there is no consensus on the definition of BIM even within firms with similar BIM maturity level, the general understanding of BIM concepts remains the same as previous literature (see section 2.3). However, having presented the current understanding of BIM within the SMAFs, the subsequent section presents the motivation for BIM adoption within the Nigerian SMAFs.

6.2.2.2 Motivation for BIM adoption

BIM has numerous benefits as identified previously in the literature (see section 2.4), such as enabling increased productivity, effective collaboration, and the effective management of information. However, in this section, the current perception of the benefits and motivation towards BIM adoption within Nigerian SMAFs are explored based on the participant's experience on the motivations and benefits of BIM adoption.

Firstly, the participants were asked to share the rationale for adopting BIM within their organisation and then the potential benefits of BIM adoption based on their experience. Almost all the participants agreed upon the benefits of BIM. However, the rationale for BIM adoption varies from organisation to organisation. Nonetheless, the frequent themes that emerged from the verbatim transcript that are associated to the rationale of BIM adoption within the Nigerian SMAFs include: ROI, cost savings, data coordination and management of design information, ease of workflow, client satisfaction, improved company image, competitive advantage over business rivals, early clash detection, better visualisation, reduced errors, and increased productivity.

The participants highlighted the following reasons as the main motivation for their firm's decision to adopt BIM.

1. Global trends, data coordination and ease of project delivery process were the motivational factors that encouraged some of the firms to adopt BIM. P03 with BIM maturity level 1 reported that BIM was utilised within their firm to deliver design projects (see section 6.2.1.4). However, further discussion on the motivation to adopt, P03 stated that their firm's interest over the years to fully adopt BIM was influenced by globalisation and the current trends of digitisation around the world

especially within construction industry. Furthermore, the firm generated a lot of design information during their projects and incorporating BIM within the organisation process of project delivery seemed appropriate and desirable. Additionally, this integration of BIM to their firm not only compatible with the process of project delivery but also simplify and ease the process of project delivery. Nonetheless, it is worth noting that this reaffirms the understanding of BIM as a process driven by technology rather than just a technology without associated process.

> “for quite some years now we have been trying to adopt BIM because of globalisation around the world things are becoming more digital especially with the construction industry and the amount of information and data that is being generated so you wanted to incorporate BIM within our organization to ease our processes. – P03”

2. An increase in project performance through effective project coordination was a motivating factor for some firms. Additionally, this indicated some evidence of increased satisfaction and productivity. Accordingly, P16 mentioned that among the main driving factors of BIM adoption within the Nigerian SMAFs is BIM potential to increase overall project performance and enhance project delivery. Additionally, BIM potential to coordinated project delivery is identified to provide more satisfaction for the user and increase productivity. Eventually, this can save the firm a lot of money during construction projects. This is in line with the BIM benefits identified in literature (see section 2.4).

> “… the driving factors of BIM is potential increase overall performance and enhance project delivery and the projects will be done in an orderly manner which would provide more satisfaction and eventually led to increase in productivity [….] because it has a lot of potential and can save a lot of money during construction projects – P16”

3. The ability for BIM to produce digital visualisation of design and construction process motivated the Nigerian SMAFs to adopt BIM (see section 6.2.1.4). P04 described the benefits of digital sketches using BIM tools such as Revit while comparing the benefits to traditional method of sketching. This shows that the firms utilise BIM tools early (i.e. right from the design concept phase) during projects. It also shows digital sketches are more effective than traditional sketches in terms of clear representation of ideas and concepts. Furthermore, the ability to digitally visualise 3D spaces and identify lapses early in the design stage is additional advantage of BIM. P04 added that the demerit of pen and paper is that vital information such as identifying discrepancy in design and a clear

understanding of the space and dimensions can be difficult and therefore it is more effective to use digital tools such as BIM tools. Additionally, the potential of BIM to visualise concept and identify lapses in the design early can support client briefing and save cost in the long run because if the client clearly understands the proposed concept design and the clear understanding of the spaces, there likelihood of rework and redesign is drastically reduced. This potential can also be transferred to the contractors and workers during construction so that they can understand what is expected. In essence, BIM tools can be utilised to digitally rehearse the entire project delivery process within the Nigerian SMAFs.

> "Actually, what really happened is that with time and experience we got to realise that even the hand sketches, there were limitations. But when you are doing the sketches on screen or when you are working with the software like Revit to sketch the floor plan because you already have the concept in your head. You get a better idea, and the concept becomes more effective. When you make the sketches digitally, you will see the dimensions, you will see the space, and you know in the 3Dimensional format, if there are any lapses with the sketches, you will see it right on the screen. But when you are using paper and pen, sometimes you might not foresee some lapses of the design until you move to a certain level then you will realise that this might not work. But when you are using your screen and software, immediately there is a demerit with the design, you will realise it as soon as possible. So, it is more effective for me to do the sketches digitally. As long as you have the idea in your head. – P04".

4. Sequel to the previous paragraph, some Nigerian SMAFs identified BIM design process ability to provide higher client satisfaction and return on investment (ROI) than traditional design process as a motivational factor to adopt BIM. For example, P11 mentioned that the benefits of BIM to their firm is the realisation of higher profit margin. Furthermore, having a BIM model from an early stage provided their firm with 3D visualisation which is more effective when presenting to their clients. Although this is similar to the previously identified motivational factor (see previous paragraph No. 3), P11 added that presenting a digital visualisation of design proposal to the clients captivate the client's attention and increase their satisfaction level. Therefore, the firms that utilise the BIM process to satisfy clients can charge 5 times the regular amount that is charge for similar design. Additionally, this indicates that integrating BIM process during the early stages of the design provides not only a higher ROI but also an advantage over firms that are not using the BIM process within the Nigeria SMAFs.

> "the most important benefits for me and the company is that people should know that you get paid more for using BIM because when you need the

> stretches using digital being process you will have 3D, a better design that is effective and efficient and we will have good rendering and 3DS for the client and making the presentation for him digital you they get carried away with the process and when you charge them no matter how expensive the price is the client will try to argue why is it expensive and you will tell you that this is how your process is and because he has seen the difference and he will still pay you the agreed price and the price is a bit higher than the other companies that do not use this process and in Nigeria if you want to get paid higher you have to use this process. I don't think my company I am using been to its fullest capacity but to our level in terms of payment you can get more than five times they are glad payment higher than the companies that do not use this process. Take for example somebody that do not use this BIM process you can get a million naira for a project and you will get 5 million naira because you will convince the client that this is what they need in visual. – P11"

5. Clash detection, data coordination and ease of design process workflow motivated some of the firms within the Nigerian SMAFs to adopt BIM as highlighted in earlier discussion (see section 6.2.2.1). P06 highlighted the BIM potential such as coordination of different design versions and clash detection (i.e., clashes between pipes, columns, and electric wires) prior to construction phase to avoid interruptions during project delivery. However, synchronising the drawings increase the accuracy of the drawings and with less interruption during project delivery, time and cost can be saved.

   > "instead of having different versions of the drawing and having some clash or discrepancy during construction when you use BIM, you're going to have a synchronised drawing and it's going to have a smooth flow during construction you don't have columns clashing with pipes or some electrical wires doing any of that interruption. – P06"

6. Additional to the previous paragraph, P05 affirmed that BIM ability to saves time and reduce rework is a motivational factor to BIM adoption within the Nigerian SMAFs. Furthermore, P05 describe the traditional method of project delivery especially during the design stage is time consuming. For example, architectural design document submitted to a structural engineer to develop a structural design is usually cross checked to confirm the accuracy. However, if the design is inaccurate, the process has to be repeated. Although the designs developed with BIM tools are cross checked, it is still faster that sharing different versions of files that are not coordinated. Hence, the ability of the engineer to utilise BIM in producing the structural design on the same model would drastically improve the accuracy of the design and reduce the time taking for cross checking the accuracy. Additionally, this shows that professional business partners such as

engineers is an important consideration to the Nigerian SMAFs when adopting BIM.

> "Of course, it does. And it is time consuming because you have to wait for him to come and make amendments you might have to take measurements and go back to draw the entire structural design and it takes a lot of time. But if he is familiar with the Revit, it saves a lot of time. – P05"

7. Accordingly, leadership from the larger firms encouraged some of the small firms to adopt BIM. P02 disclosed that BIM is not utilised within the firms but elaborated on the firm's dependency on outsourcing some of their design tasks such as 3D design for visualisation to other firms with the capability to deliver such task (see section 6.2.1.4). However, P02 recommended that leadership from larger firms with higher BIM practice would encourage the Nigerian SMAFs with lower BIM maturity level to adopt BIM.

> "No, the strategy for us to achieve that is if the big firms in this country, maybe the selected big firms can be convinced to start using it, then the smaller once can follow. – P02"

In light of the above discussion on the motivational factors of BIM adoption within the SMAFs, it is equally important to discuss the current challenges of BIM adoption within the Nigerian SMAFs in order to fully understand the current situation within the Nigeria context. Thus, the subsequent section presents a discussion of the current challenges within the Nigeria SMAFs as identified by the participants.

6.2.2.3 Current Challenges identified by the firms.

BIM has numerous challenges as identified previously in the literature (see section 2.5), such as organisational, technical, human, business, and legal challenges. However, the current challenges towards BIM adoption within Nigerian SMAFs as identified in the verbatim data/transcript based on the participant's experience are presented in this section.

1. Cost related challenges have been identified to have significant influence towards BIM adoption within the Nigerian SMAFs. Cost related challenges include investment funds needed to acquiring BIM knowledge, training, and hiring of personnel, investing of IT infrastructure, and changing from tradition to BIM process. P03 mention that cost is a major factor particularly to training of

employees since the training are usually conducted through organising seminars. This indicates that firms that intend to support the adoption process of BIM through upskilling and reskilling of their employees need to invest in training. Similarly, most employees need to acquire BIM knowledge and understanding through formal training such as learning institutions programmes, workshops, conferences or inhouse training which also requires funds. Therefore, cost related challenge might hinder the BIM adoption process of the firms with low funding.

> "Cost is one of the major factors and then training as well. And since training requires you to organise some seminars and so on therefore it required some funds as well. – P03"

Additionally, P04 reported that IT/BIM managers are very expensive and therefore when investing, their firm prioritise on the important aspects before considering other aspect. This indicates that recruiting a BIM personnel is expensive and as such there is need for the firms to prioritise their budget. However, a firm that does not realise a substantial profit margin might not be motivated to invest in recruiting BIM professionals even though it improves BIM adoption within the SMAFs.

> "... we are planning on bringing a full-time IT manager that will manage our IT section, our drawings, archives, software upgrades and everything so we are thinking of that, but you know it comes with a cost and those IT guys are sometimes very expensive. I say said in Nigeria, you look at the necessary part and you finish with the necessary section then you move to the other areas. but basically, right now the IT section is managed by our partners. – P04"

Similarly, the cost of BIM infrastructure has been identified as a challenge that hinders BIM adoption within the Nigerian SMAFs. P03 reported that it is expensive to acquire BIM infrastructure such as BIM software and therefore it is perceived as a challenging factor that hinders BIM adoption within the Nigerian SMAFs. However, BIM infrastructure such as hardware, software and network are integral to successfully adopting BIM process. This means that the firms that cannot afford BIM infrastructure resort to using unlicensed BIM tool within their firms.

> "The cost of the BIM software is somehow expensive to acquire the software that is used for the BIM so I can see the cost is also a challenge that we have been facing – P03".

In addition to that, P06 affirmed that well established firms such as the large firms or firms that realise high margin of profit can afford to invest in BIM due to the expensive cost associated to BIM while firms such as SMAFs that are not well-established use unlicensed BIM tools (i.e., cracked version). This affects the ability of the BIM manager to fully explore the potential of the tools thereby affecting the BIM delivery process.

> “to get the correct BIM cost is expensive and it is only the well-established firms that can afford it because of the price and then usually the software that we use here are cracked versions. So, with the cracked version you cannot exactly unlock the access and you cannot be a BIM manager if you are using the crack version, so you'll have to buy it and get the licence good and what not. – P06”

However, P04 reported that BIM adoption might be encourage within the Nigerian SMAFs through the reduction of the license fees because jobs are sometimes unavailable for a duration of 6 months therefore there is need to manage the financial resource available and prioritise the firms spending budget.

> “Reducing the cost would allow firms to purchase, especially in Africa. $2,500 is a lot of money and for you to purchase a subscription for a year. You might not get a job for 6 months that will cover for the licence and you must pay salaries and office expenses. – P04”

Additionally, financial incentivisation maybe required to encourage the employees during the change process from traditional to BIM project delivery process and as such, financial funds are required for the firms to effectively develop incentive schemes within their firms. P04 mentioned that financial incentives are provided to their employees that is additional to their salary to motivate them particularly when they completed a task.

> “So normally what we do is we use psychology for them of course there are incentives from time to time especially apart from their salary whenever they finish a good design, we reward them for that, and we always encourage them and give them motivational words and appreciate the effort. – P04”

2. Challenges related to lack of awareness of the government and regulatory bodies was considered to hinder the adoption rate of BIM within the Nigerian SMAFs. P04 mentioned that the Nigerian government are not really interested in BIM adoption because they are not aware of the potential value of BIM within the industry. This indicates that an increase in the government awareness of BIM value might result to the government to push the adoption of BIM. The perception of the participant within the Nigerian SMAFs is that BIM adoption is more likely to improve between the regulatory bodies, professional bodies, firms and professionals when the government show interest in BIM and provide support or mandate BIM usage.

> “to be honest the government are not into BIM here. At least there is little adoption of BIM in schools now, but their regulatory bodies and the

> government need to do more on this aspect especially the approval body. So that they will encourage firms to encourage firms to present BIM design but there is no current regulation now or any law that push for adoption in Nigeria there is none. So, whatever you present is what is the accept. when government comes in and encourage or put it among the processes requirements for getting approval for any building development in Nigeria, that is only when people professionals and companies will be alerted and see the need for the adoption of the BIM process. Almost everything in Nigeria deals with government. It is only the government that can encourage that, and the approval bodies can push such processes. if they like it everybody will embrace it. – P04"

Furthermore, most countries with successful BIM adoption have a degree of government intervention, including BIM policies, mandates, and recommendations. However, although building codes (such as British Standards and Codes of Practice) are generally implemented by regulatory bodies and construction control agencies, there is no explicit legal provision exists in Nigeria for the use of BIM in the construction industry.

3. Similarly, lack of support from the government, regulatory bodies, educational institutions and business partners such as larger firms due to government lack of awareness has been a challenge to BIM adoption within the Nigerian SMAFs. P01 reported that there is no government support through legislative backing or government intervention to support BIM adoption. This indicates that due to the lack of government legislation and intervention, BIM adoption by the regulatory bodies, firms and clients has been slow.

> "Well, I think it needs more support from the government side through a legislative backing some sort of intervention or some government intervention. – P01"

Similarly, P04 reported that there is need for the educational institution to develop BIM curriculum that will equip the future industry professions with BIM skills and competency that would contribute to the uptake of BIM adoption within the industry.

> "They do not have BIM in their curriculum and staff are not encouraging the students to learn such systems […] overall, we need to do better. – P04"

4. Furthermore, the lack of BIM standards and clear guidelines for implementing BIM within the Nigerian building sector is perceived to hinder BIM adoption within the Nigerian SMAFs. P02 disclosed that there are no BIM standards such as EN BS ISO19650 to adhere to within the Nigerian SMAFs. However, P02 acknowledged

the availability of other standards such as British standards and proposed building fire code within the Nigerian building sector.

> "No standards for now […] we use BS code. British standards code. But of recent, I know NIA is proposing Nigerian Code but what they are dealing with is mainly fire code. Okay we have building codes. – P02"

Additionally, P01 added that the firms adhere to international standards such as LEEDs certification and British Standard codes although it was not a requirement by the government or regulatory body. This indicates that although there are standards within the Nigerian building sector, the standards are not helpful since they are not related to BIM adoption and therefore firms highlighted the need for BIM standards and guidelines to assist the Nigerian SMAFs through their BIM adoption process.

> "Some of us adhere to LEEDS Certification and other standards and we strive to adhere to those international standards but from the national or Nigeria side of it is not required by the government for any accreditation. I am not aware of any international standards that is a requirement. – P01"

5. Furthermore, the lack of trained BIM professionals within the industry have contributed the slow adoption within the Nigerian SMAF. P05 mentioned that their firm do not have a digital manager (i.e., IT/BIM manager) that is responsible for overseeing, coordination BIM. However, firms that acknowledge the presence of an IT manager such as P07, reported that the IT manager lacks BIM knowledge and therefore there is little assistance that can be offer with matters related to BIM. However, BIM professionals and BIM enthusiast/advocates play significant role during BIM adoption process though motivating their peers and championing BIM adoption process within the SMAFs. Therefore, the lack of trained professionals hinders the BIM adoption process within the Nigerian SMAFs.

> "…for now, we don't have. – P07"

> "Yes of course we have. But they are not familiar with Revit software, so they are already familiar with web email and those sorts of things. – P05"

6. Lack of professionalism within the SMAFs has been identified as a major challenge which is often associated to the negligence of the government and regulatory bodies. P08 mentioned that contractors are valued more than the professionals and the increased the amount of unprofessionalism within the sector.

> “Yes, there is, if the government is very serious about it. If the government is serious and committed and eliminates all those powerful contractors and pays more attention to the professionals that is where, we will get it right. – P08”

However, P15 suggested that the level of corruption and unprofessionalism can be reduced through enforcing legal actions on the contractors or professionals that did not adhere to the standard required channel of project delivery process within the sector. Furthermore, indications show that some contractors offer bribes to push their project. Therefore, the government and regulatory bodies need to commit to address the challenges of unprofessionalism in order to facilitate BIM adoption within the sector.

> “No. it is because of the level of corruption in the country. It is the issue of corruption not any other thing. Because you'll find out that the contractors are more powerful than the Professionals. That is why there is no professionalism, and the contractors can just deliver projects without following standard due process. If something happens, they just pay their way out and no legal action would be carried out on them – P15”.

6.2.3 BIM Adoption Process in Nigerian SMAFs

Rogers (1995) five stages of innovation adoption process is used to explain the current BIM adoption process within the SMAFs as discussed previously (see section 3.3). The five stages include knowledge acquisition, persuasion strategy, decision making, implementation process, and confirmation (see section 3.5). The participants were asked questions not only related to the current BIM benefits, challenges, or motivational factors but also the BIM adoption process within their firms. The participant collated shared experience is then transcribed and coded. This was further synthesised to establish a relationship matrix between the stages of the adoption process and the firm’s sizes and BIM maturity levels. However, from the relationship matrix in Figure 6.3, the colour code is a representation of the number of referenced discussions around the subordinate themes ranging from red representing the lowest number to green which represents the highest number of discussions. Furthermore, there is little discussion around persuasion strategy from firms that are characterised as medium firms (i.e., number of employees between 51-250) and low BIM maturity level (i.e., at level 0).

	A : ID:BIM Level = Level 0	B : ID:BIM Level = Level 1	C : ID:BIM Level = Level 2	D : ID:Firm Size = Micro <10 Employees	E : ID:Firm Size = Small 11 - 50 Employees	F : ID:Firm Size = Medium 51 - 250 Employees
1 : Adoption Process	4	17	41	14	26	22
2 : Confirmation	1	2	6	2	4	3
3 : Decision Making	2	6	9	4	6	7
4 : Implementation Process	1	2	10	2	4	7
5 : Knowledge Acquisition	1	5	13	4	10	5
6 : Persuation Strategy	0	3	5	2	6	0

Figure 6.3: Showing Matrix Between AP vs BL - FS.

The discussion of the BIM adoption process within Nigerian SMAFs is presented in the subsequent sections.

6.2.3.1 Knowledge Acquisition

Knowledge acquisition refers to when the individual is first exposed to an innovation but lacks information about the innovation. In the context of this research, during this stage, the individual has not yet been inspired to find out more information about BIM. However, within the Nigerian SMAFs, participants have identified different channels through which the individuals become aware of the existence of BIM and becomes interested in understanding BIM functions. The channels highlighted include conferences, seminars, workshops, online search engines, social media, promotional emails and advertisement, discussion with business partners. Additionally, P05 indicated that the channel for knowledge acquisition in their firm is mainly through their colleague, peers and superior, such as a project coordinator or top manager.

> "… we have a project coordinator who does that and sometimes our top manager… – P05".

Furthermore, P03 highlighted the role of the firm in providing workshop and seminars to expose the staff to BIM. This shows that the Nigerian SMAFs are utilising channels such as workshops and seminars to provide knowledge to the employees. It also reflects upon the importance of providing the employees with appropriate knowledge and information about BIM.

> "We have been recently trying to organise some workshops and seminars to educate our staffs and employees and BIM and get more information about that. – P03".

Similarly, P01 established that their firm holds a mandatory workshop on a regular basis, and the company usually invites international business partners to expose employees to current global trends and information. Furthermore, the firm develops, plans, and executes in-house training on aspects that are particularly of interest. However, individuals also upskill or learn new skills by themselves and teach them to other colleagues so that new information can keep circulating within the firms. Therefore, there is an element of organisational learning culture and encouragement by the firm's management.

> "…the company makes it mandatory to attend a workshop. So, we do have events, workshops, seminars consistently and every member of the department goes to… But aside the seminars and the workshop we also do something called in house training where I can look up a particular aspect of what I think is happening now and try to learn it on my own and then try to train my other team members on those new aspects, so that way we keep information going round among us. – P01"

Additionally, firms with low levels of BIM usage also agreed upon the evidence of self-learning through training by their employees. However, knowledge is acquired through individual research and curiosity and then transferred to the top manager or individual in a position to make decision. This indicates an element of a bottom-up approach towards decision making within the Nigerian SMAFs. Furthermore, knowledge sharing within the firms has been identified to be crucial to change management process. This reduces the difficulty in the change management process because the stakeholder's opinion (i.e., employees, top managers, staff) is captured and included in the process. Skipping this stage might lead to emotional dissonance in the persuasion stage and eventually affect the implementation stage. For example, P02 mentioned that employees learn a digital tool and integrate it into their workflow. However, if the employee recognises a benefit or advantage of the digital tool after the trial process, the individual can share the knowledge and try to convince the management or person with the position to decide. This does not only indicate a bottom-up approach to acquiring knowledge and persuasion but also a strategy for including the stakeholders involved in BIM usage such as employees and top manager in the early stages of BIM adoption process. Furthermore, it is important that in addition to the acquiring BIM knowledge, individual that demonstrate the potential benefits of BIM can leverage that knowledge during the persuasion stage as it is more likely for the firms to be persuaded when they recognise the benefit of BIM.

> "Yes, it is normally through training, but people need to see it working and see the advantages before they can go for that. Like there was a time when we are using power draw. They call it power draw a software. In my office, I must convince them to change to AutoCAD. And when they saw what AutoCAD was bringing, they now changed completely. – P02"

Participants shared their process of knowledge acquisition to be influenced by the organisation culture, management support, top management. Although the frequency of training from small firms is still relatively low (annually or biannually) and usually provided after annual leave to refresh the employee's knowledge, the organisational culture always encourages the employees to use the available digital tools such as search engines to seek for new information. For example, P04 discloses that the firm always encourages the employees to individually learn and search for current issues through taking advantage of the available search engines such as Google or YouTube. This alludes that online BIM resources such as websites, blogs, forums, social media etc. are utilised as a channel of acquiring BIM knowledge within the Nigerian SMAFs.

> "… we normally acquire knowledge individually using the available tools such as YouTube. – P04"

From the discussion, it could be deduced that online BIM resources, workshop, seminars and conferences can be a source of BIM knowledge and these can be organised within the SMAFs or in collaboration with external partners such as learning institutions. However, BIM knowledge can also be acquired through external channels such as regulatory and professional bodies (i.e. NIA and ARCON). Theses external channels organise annual events to discuss contemporary issues, research and product presentations and, lectures which are delivered by stakeholders including academia and industry partners. Furthermore, P01 mentioned that business partners such as international organisations are among the motivational factor for BIM adoption within the Nigerian SMAFs because the business partners exposed their firm to BIM process of project delivery while collaboratively working on a Nigerian ministry of works project. Similarly, P02 mentioned that large firms usually request for certain processes such as BIM process from the smaller firms and contractors and therefore this exposes the SMAFs to BIM in order to meet up with the job or project demand. Therefore, external business partners, learning institution, regulatory and professional bodies are crucial in acquiring BIM knowledge within the Nigerian SMAFs.

6.2.3.2 Persuasion Strategy

Persuasion strategy refers to the methods used in convincing individuals to accept BIM and it depends on the source of the knowledge. As discussed in the previous section, the initial BIM knowledge can be exposed (i.e., create awareness) to the firm through an individual (employee or top manager) or top management (senior leader). An individual such as employee may not be in a position to decide the amount of resources to invest in BIM, while the top management usually have the power to assign resource to invest in BIM within the firms. In a top-down approach, the top management can decide to skip the persuasion stage. However, this means that only the top management are convinced of BIM usefulness, and this might affect the individuals during the implementation process. P04 mentioned that although they have never experienced any resistance from their employees due to their willingness to learn attitude, the firm provides training, infrastructure and outlines the benefit of gaining knowledge for their employees. Such benefits highlighted to the employees include the acquisition of intellectual knowledge and skills that would be a valuable asset to the employees currently and in the future. This indicates that the firms educate the employees on the value of BIM not only to the organisation but also to the employees. Furthermore, individual traits such as willingness to learn and lack of resistance to BIM has been highlighted to be crucial during the persuasion stage.

> “We have never got any resistance from our staff because they are always ready to learn. That is one of the things that we look for when recruiting. We look for people that will be loyal, people that are ready to learn, people that are ready to improve and we usually get the younger minds that are always ready to learn who are full of energy. We always tell them that they are helping themselves for learning because when we train them and give them this knowledge. In the long run they might not be with the company forever, but they will have the skills and that is the best asset we can give to them. – P04”

On the other hand, for firms that acquire knowledge through employees, participants have highlighted the importance of BIM users to perceive BIM to be useful and beneficial and the ability to demonstrate the benefit of BIM. This ability will enable the individual not only to persuade their peers or colleagues but also the top management. For example, BIM has been identified to save time, cost, better visualisation, identify clashes, and manage project information (see section 6.2.2.2). However, P02 mentioned that firms are usually interested in the advantages and practical application of the new technology and, therefore, the firm are convinced when the individual demonstrates the advantage (time that BIM saved) during project delivery.

> “yes, but people need to see it working and see the advantages before they can go for that […] So, by the time they see how fast the person that is using it to deliver... Because what people want to know is that how fast is the new technology and what are the benefits […] nobody will have to tell them, in fact, they will just accept it wholeheartedly. – P02”

From the discussions, the persuasion stage is crucial to the subsequent stages because for the Nigerian SMAFs that practice the top-down decision method and decided to skip the persuasion stage, it might be difficult for the individuals (employees) that are not convinced to accept and integrate BIM effectively within their workflow and this would have a negative impact on the subsequent BIM adoption process i.e., implementation and confirmation stages.

6.2.3.3 Decision Making

Decision making stage refers to when the individual takes the concept of the change and weighs the advantages/disadvantages of using the innovation and decides whether to adopt or reject the innovation (Rogers, 2003). Decision making is usually dependent on the empirical evidence provided. Within the Nigerian SMAFs, decisions are usually carried out by a few individuals due to the size of the firms. However, factors that determine the type of decision are who makes the decision and whether the decision is made freely or implemented voluntarily. Furthermore, the discussion from the previous BIM adoption process sections (knowledge acquisition and persuasion strategy) indicated that decision making method within the Nigerian SMAFs can be classified into bottom-up approach or top-down approach. considering these, three types of decision patterns identified are individual decision, collective decision, and authority decision. Additionally, the individual decision pattern is a bottom-up approach, and the authoritative pattern is usually a top-down approach. However, the collective decision pattern can either be a top down or bottom-up approach.

6.2.3.3.1 Individual

Individual BIM decision pattern is when an individual (i.e., employee) decides to experiment and integrate BIM tool to their current workflow to deliver projects. In the Nigerian SMAFs context, the individual pattern is commonly practiced. P07 mentioned that an individual usually decided to use new technology or process to deliver design project such as BIM. This initiative is accepted within the firm because the firm is more interested in delivering the project rather than the tools or process used in achieving the goal. However, this indicates that individual decision patterns are acceptable due to the flexible organisational policy that enables experimental culture. Furthermore, this shows that the employees have innovativeness and are eager to try new innovations within the Nigerian SMAFs.

> “If an individual decides to start using a new software or a work process it is something that the organisation will accept provided it can be used to achieve the standard of the company. – P07”

Similarly, P05 agreed that the current BIM decision pattern is individual and optional. However, the management encourages BIM through training due to the benefits realised during project delivery. Furthermore, it is important for the employees to decide whether they will actually use BIM at this stage because the implementation stage is reliant on the outcome of the decision stage.

> "It is an individual decision, because if it is up to the management, they will force everyone to use the Revit. It saves time, it is easy and that is why the made decision for everyone to go to the training. – P05"

Nonetheless, participants from firms with higher BIM maturity level also described the current BIM adoption decision process to be individual. However, P01 as the head of the unit (see Table 6.1) disclosed that there is flexibility on the choice of the type of technology used within the unit. Furthermore, P01 stated that, with regards to related technology discovered by an employee, there is a process of review and validation before approving the technology to be adopted if the training process would affect the employee's productivity. This process is conducted by HR if in-house training is required, otherwise the employee can train without approval. This indicates that although there is some level of flexibility in the choice of BIM technology, the individual would have to follow a review process of the BIM technology when requesting management support with infrastructure or training. This also helps the firm to document the productivity of the employee and make informed decision as to how beneficial the introduced BIM technology is to the organisation.

> "As of now I will see that it is individual, as long as you are the head of a unit you are at liberty to choose the type of technology used there and other related new technologies you discovered. if it is one of your subordinate that finds the new information, they do need to bring it to you for review before you can give a go ahead for them to train on it. But as long as you are the head of the unit what you need to do is, if you get such information, it is fine to inform the HR saying that you have an in-house training which will be lasting this hour because you will be doing work hours which is a productive timestamp. But aside from that you can go ahead and do training without seeking any approval. – P01"

6.2.3.3.2 Collective

Collective BIM decisions are made collectively by all individuals. There is evidence of collective decision within the SMAFs. For example, P02 mentioned that because the management are not practically delivering the designs and not fully familiar with the trends in terms of tools and processes, individuals or employees tend to share information and knowledge of new trends. This organisational culture helps the employees to collectively decide to use technology such as BIM tools to deliver their project. This does not only indicate that there is an element of collective decision making within the Nigerian SMAFs but also confirms a bottom-up approach to knowledge and persuasion strategy.

> "At times its normally, because the top management don't really use it, it is only the staff if they see it somewhere, they discuss with the management and say "ah... See what this office is using oh..." they feel it's better. So collectively they make the decision. – P02"

Similarly, P06 discussed the decision-making process of adopting BIM within their organisation to be a collective approach from the bottom-up. However, P06 highlighted the collective decision approach in their firm include the top management which is contrary to P02 that highlighted their management are not interested on the BIM tools or process used to deliver the project. This enables the employees to be supported by the management through investing in BIM adoption process (i.e., providing infrastructure, flexible policy, and training). Furthermore, P06 stated that the employees are usually self-taught (with regards to BIM tools) and the management are approached after the employee's collective decide on requesting the management support to officially use BIM. Therefore, this scenario of employees taking the initiative to learn BIM makes the subsequent stage of implementation easily acceptable by the employees since there is indication of interest in BIM within the firm.

> "The decision is usually from the individual. Lead an individual might say that is this BIM software and I really like it and I think it is going to be good for my work and it is going to be very effective for my work. so, the person just goes ahead to learn and train himself to whatever level that he can train himself to. but now when the other people see that this person is trained and it's good, and they wanted that type of training also they can decide to collectively apply to the management to send them out for training so now this management is going to give in an approval whether they can go, or they cannot go so somehow it still boils down to the management or you can decide to do it solo. – P06"

6.2.3.3.3 Authoritative

Authoritative BIM decision method refers to decisions made by individuals (top managers or management) that are in positions of influence or power which is often referred to as the top-down approach. 8 of 17 participants have mentioned that the decision-making process of their firm on BIM adoption is authoritative in nature. This means that the management identified the benefits of BIM and decided to adopt BIM throughout the firm without considering the opinion of the employees. P04, for example, describes their firm's decision-making process as stemming from management (top-down approach). However, it is easier to apply a top-down authoritative decision-making approach due to the firm's agile nature (being a small size). Furthermore, the small nature of the firms means that there are less people involved in the decision-making process at the management level. Additionally, P04 stated that their firm decision to adopt BIM is a reflection of the current new trends such as BIM within the industry. This indicates that their firm are updated on the current trends through knowledge acquisition. Furthermore, this affirms that authoritative decision method is usually a top-down approach within Nigerian SMAFs. However, with the limited resources available, the firm managed to train the employees in batches as a strategy to reduce the cost of overall BIM adoption, while working towards fully adopting BIM. Additionally, the employees that are trained would transfer the knowledge to their colleagues and this creates a learning system that upskill the competence of the employees.

> "Normally is for the management and since the company is very small the decision is very easy which is between 2 or 3 people among the management example they might say you need this or we need to adopt this or something is coming up and there is a new trend regarding BIM so let's push our staff to learn it or let's learn it ourselves and then train our staff to get it so what you do is we learn things then we train our staff. – P04"

Similarly, firms that have flexible policies that enable the employees to experiment new innovative processes and technology such as BIM can decide to mandate BIM usage within the firm is convinced about the BIM potential value. For example, P03 stated that their firm encourages innovation and enables the employees to try new technology such as BIM tools. This led to an employee (BIM evangelist or enthusiast) suggesting BIM to the management board and the management to assign the employee as the BIM champion which would lead the company employees towards effectively adopting BIM.

> "To be frank it is one of the employees that has been using BIM and due to our company's policy of encouraging innovation he came with that and give it as a suggestion to the company's board and the company decided to give it a try. So, our company is open to innovation. So, after he gave the decision to our company and the board approved BIM… – P03".

6.2.3.4 Implementation process

The implementation process refers to when the individual employs the innovation to a varying degree depending on the situation. During this stage, the individual also determines the usefulness of the innovation and may search for further information about it. However, the implementation process within Nigerian SMAFs that have multiple units usually starts with the architects and is initiated after the decision-making stage. P03 disclosed that the implementation process of BIM is dependent on the BIM champion that was assigned by the firm's management board. Additionally, the BIM knowledge and experience of the individual to be considered as the BIM champion is considered for effectively guiding and leading the employees through the process. Therefore, firms within the Nigerian SMAFs should appoint BIM champions that would lead the firm towards a successful BIM adoption by considering not only individuals with the BIM knowledge and experience but BIM evangelists and enthusiast.

> "So, after he gave the decision to our company and the board approved BIM, he was made the leader of the BIM because he has more experience than any other person within the company because he knows more about BIM and they believe he can lead and guide other employees on how to effectively use and benefit from BIM. – P03"

Training is an important factor to consider during the implementation process of BIM within SMAFs. Due to the small nature of the firms and limited resources, it is sometimes difficult for the firms to invest in training and other infrastructure needed to implement BIM. Therefore, the firms train their employees in batches or train the minimum number of employees needed to start the implementation process. The firm developed a culture of organisational learning to enable the employees with a higher level of knowledge to transfer the practical and technical skills to other employees. This often more cost effective for the firm. For example, P05 mentioned that once a year, 3 employees are trained on BIM tools such as Revit and priority is given to those that do not have knowledge of BIM tools.

> "Once a year at least three or 4 people go for a training from different sections but then the rest of the train individually... – P05".

Similarly, the cost of the software is considered during BIM implementation and, as such, the same process as the training strategy is adopted for the software license. Participants mentioned that a single license is usually bought for the trained individual within Nigerian SMAFs to explore and evaluate the benefits of BIM to their firm before subsequently purchasing more license for employees. For example, P02 mentioned that the first step was to train a single person on how to use the BIM tools. Then the trained individual will subordinate subsequently train and demonstrate the BIM tools to other employees. Furthermore, the cost of the BIM tools is usually a major consideration and due to the limited funds of the firm, a single license is purchased, and subsequently additional licences are purchased for the BIM software.

> "… they will get it for one person. They will get the software and let the person that brought it use it or go and learn from the other office then he will come and

> show others. From there, we will be buying it in parts until everybody has it. – P02”

Developing organisational guidelines, strategies, and standards is an important consideration when implementing the BIM process within the Nigerian SMAFs. Participants have identified the need to have a process of project delivery which also includes the enabling tools needed for the process. It is perceived that the use of multiple BIM tools within the SMAFs may lead to interoperability issues and confusion within the firms. Therefore, it is recommended to have a standard BIM tool that would be used within the firm during the implementation process. For example, P05 pointed out that the use of multiple software creates difficulty in sharing information and leads to problems. Therefore, their firm decided to mitigate the problem of coordination of data and information through having a standard requirement and process of project delivery within the firm through recommending similar BIM tools. Additionally, the selection of similar BIM tool simplified the learning curve of the software since almost all the employees are using the same tool and peers can always assist with any technical issue.

> “They said earlier the problem with using so much software is that it creates more problems… It is time consuming to the architectural teams and other teams… It is a problem for the company…so they make everyone use and learn the same software. – P05”

Furthermore, P03 reported that following the decision of their firm to implement BIM in future design process, there have been policies developed to ensure BIM practice within their firm is sustained. This indicates that it is important for the Nigerian SMAFs ensure that there is a guideline or strategy in place to support BIM implementation so that the employee do not revert to their old method of project delivery.

> “From the current projects that we're having now and all future projects that we're having we try and make sure that BIM is implemented in all our designs. Yes, that is one of **the policies of the company as from now to ensure it has been practiced**. So, we have created different policy to make sure that BIM is being adopted. – P03”

Furthermore, P03, P04 and P05 highlighted the importance of providing financial incentivisation as a strategy to encourage the employees to continue utilising BIM process with the SMAFs.

> “…of course, there are incentives from time to time especially apart from their salary whenever they finish a good design, we reward them for that, and we always encourage them and give them motivational words and appreciate the effort. – P04”

From the above discussion, managing resources, reducing cost and mental effort is important during the implementation process of BIM within the SMAFs. Similarly, the ease of use of the BIM tools motivates the employees to apply BIM process in their current workflow. However, the development of change management board and BIM champions is crucial to the success of BIM adoption within the SMAFs. Additionally, regular training and workshops should be encouraged to support the implementation process because it makes the employees adjust and understand the process faster. Finally, developing organisational guidelines and strategies should be considered as a persuasion strategy to prevent employees from reverting to the old method of project delivery after the implementation of BIM within the firms.

6.2.3.5 Confirmation

The confirmation stage is sometimes referred to as the continuation stage. Confirmation happens when the individual finalises the decision to continue using BIM or stop using BIM. This stage is both intrapersonal (it may cause cognitive dissonance) and interpersonal, as it confirms the group's decision (Rogers, 2003). However, in the Nigerian SMAFs context, BIM users' opinions can be grouped into two, including those that are at the testing and have not come to a decision as to whether the firm would continue or reject and those that have accepted the technology. Additionally, the benefits of BIM make it desirable for firms to continue using BIM. For example, P01 mentioned that the management agreed to continue using BIM due to the increase in productivity, reduction in time taken to complete task, and the number of mistakes that have been mitigated (increased accuracy). Therefore, at the confirmation stage, the management determine whether BIM should be permanently or discarded through an evaluation of BIM benefits to the firm and how well is BIM utilised within the firms. These benefits may include increased productivity, accuracy, and reduction of the time taken to complete task. Furthermore, this shows that the information that can be embedded in the model and managed through a BIM delivery process has encouraged the Nigerian SMAFs to continue using BIM and invest more resources both financial and intellectual. Nonetheless, P01 reported that although BIM is implemented within the firm, there is a tendency of reverting to the old ways of project delivery through the misuse of BIM enabling tools. However, as discussed in the persuasion and decision stage, this might be common in firms that skip the persuasion stage and authoritatively decide to implement BIM without consulting or considering the opinions of the stakeholders (such as employee) involved in adopting the BIM within the firms.

> “Well, I think that the speed of work and the amount of productiveness that comes off it simply makes it impossible for the management to discard. To be honest the management started to talk about moving to BIM, but now that he have started doing it and they can see the piece at which we are doing our work and the amount of information we put into the models for the other departments to work with, I think it is next to impossible for them to do away with it. so basically, to answer your question, **I think it is about how well you use it that will determine whether it stays on or it is discarded.** Because you can have a full BIM capable software, but you are still using it as a rudimentary tool like how you are using your old 2D software. This means that the management would not see any reason to invest in BIM if there are no positive benefits to the company. But I think for us, the productivity that has come up with using BIM and the number of mistakes you have reduced would encourage the management to keep using BIM for a long time. – P01”

Additionally, P02 affirmed that during the confirmation stage, BIM benefits is an important consideration. However, the speed at which the employees learn and utilise the technologies is equally important in order not to hinder the progress of the ongoing projects within the firms. Nonetheless, management support such as organising workshop and providing training can be beneficial in reducing the time taken for the employees to learn and apply BIM to their project delivery process. Therefore, management support facilitates the rate at which employees utilise BIM which makes it more likely to confirm the continuation of BIM usage within the Nigerian SMAFs.

> “if it is documented it has benefits, they will not stop at getting it. It is how fast the staff can learn and cope with it. And how applicable they can use it on the ongoing projects. They wouldn't want anything that will stop their progress in achieving the ongoing progress... – P02”.

In addition to the concerns raised on employees reverting to old practices after BIM implementation, P03 reported that the decision to continue integrating BIM into all future design has been made by the management and organisational policies have been put in place to ensure that the decision is adhered. Thus, the success in the confirmation stage becomes evident when individuals such as employees within the firms are familiar and adhering to the BIM process rather than reverting to the old process of project delivery. Additional employees need to make a decision to continue utilising BIM and therefore including the employees at an earlier stage during the persuasion stage and decision stage may avert the difficulty that may arise from employees not full confirming to continue using BIM process within the firms.

> “From the current projects that we're having now and all future projects that we're having we try and make sure that BIM is implemented in all our designs. Yes, that is one of **the policies of the company as from now to ensure it has been practiced**. So, we have created different policy to make sure that BIM is being adopted. – P03”

Considering the presented findings on the current BIM adoption status and understanding of the BIM adoption process as elicited from the interview participants, the next section presents the analysis of the factors that influence BIM adoption within the Nigerian SMAFs under the subsequent superordinate themes and subordinate themes that emerged from the verbatim transcript.

6.2.4 Individual Competence Analysis

The subordinate themes related to individual competence are employees, top manager, and digital manager as shown in Figure 6.1. However, in the subsequent sections, the analysis of the individual competence is presented.

6.2.4.1 Employee

It was perceived that firms with relatively high levels of BIM usage focus more on the quality and competence of an employee right from the employment stage. P04, for example, stated that when recruiting, the company looks for traits in employees such as loyalty, willingness to learn, and motivation. The rationale for this is to have competent individuals that can easily be trained with less resistance. Furthermore, a few (3) of the interviewees mention that when it comes to hiring employees, a younger person with BIM knowledge is more likely to have an advantage over an older person.

> “We look for people that will be loyal, people that are ready to learn, people that are ready to improve and we usually get the younger minds that are always ready to learn who are full of energy. We always tell them that they are helping themselves for learning because when we train them and give them this knowledge. In the long run they might not be with the company forever, but they will have the skills and that is the best asset we can give to them. – P04”

In addition to the emphasis on skill competence, the participants highlighted the importance of the employee attitude to willingly accepting change and learning during recruitment as shown above. P11 concurs, pointing out that the staff's lack of resistance and willingness to learn contributed to the firm's relatively higher level of BIM usage when compared to others.

> “We have never got any resistance from our staff because they are always ready to learn. – P11”

Similarly, P04 added the priority importance of skills and competence over the qualification of the individual. For example, in the quote below, the first thing the hiring management checks in a potential employee profile is the skills the individual has with regards to the BIM process, rather than the qualification the individual possesses.

> “Actually, we don't need qualifications certificate or whether you go to school or not if you know BIM processes because certificate is different from the skills. so that is the first thing we check, if there is someone that is not an architect and has learnt this process and has the capacity, we don't mind employing him rather than the person that has the certificate but doesn't know anything about BIM processes because we don't need him. we deal with people with skills not really certificate in our own firm. – P04”

On the contrary, a firm with relatively low BIM usage can be linked to the attitude of their employees. They indicated that their employees perceive BIM tools to be more difficult than the traditional tools they are used too. For example, P12 from a relatively low BIM usage firm, reported that Revit is more complex than AutoCAD and that is because the employees are reluctant to change.

> “I believe it is honestly harder than AutoCAD it's a bit complex. That is why they are reluctant in learning it. – P12”

Similarly, another relatively low-level BIM usage firm indicated that when it comes to recruitment of employees, they basically are more concerned with their formal educational qualifications rather than their level of skills. For example, P13 mentioned that top management usually look at an individual qualification such as degree to gauge the level of competency. P12 added that the rationale behind their decision is because most of the applicants needed a chance to get the initial experience needed for the job since they do not have a prior record of experience.

> “I don't know really you know employment comes from top management not department itself so competency now usually just look at your credentials and if you have the valid credentials which includes studying a degree and you've done the basics you've gone to school and you have a degree and everything, they can employ you. the thing is you get a shot at the basic level because not everybody wakes up with experience you must be given a chance at it. So yeah, that is what they do like you have your certificate you've been to school, and you're certified to do this job they will give you a chance at it. That is what they do. – P13”

Considering the above analysis, P04 and P11 are both firms with BIM maturity level 2 while P12 and P13 are firms with BIM maturity level 1. This indicates that the firms with BIM maturity level 2 consider additional criteria such as BIM experience when hiring their employees while the firms with BIM maturity level 1 only consider educational qualifications.

6.2.4.2 Digital Manager

In this context, the digital manager is an individual responsible for championing and leading IT or BIM activities. For the BIM adopters, this could also be the BIM manager and for non-adopters this could be and IT manager. However, there could be both IT and BIM manager roles within the Nigerian SMAFs. From the interviewee perspective, few firms acknowledge the presence of a BIM manager, while most of the firms claim that they do not have an IT manager. However, the interviewee also showed some evidence of IT business units that assist in troubleshooting their hardware. Although they mentioned the availability of the IT business unit, concerns about the unit not having technical knowledge of BIM tools were also highlighted. For example, P01's firm, which is medium sized, explained that they have a tech-savvy IT business unit responsible for the infrastructure and network facilities and are dependable for troubleshooting the challenges encountered.

> "Sincerely yes, we do have a sizeable IT unit but on the building services side, we are quite tech savvy people as well. So basically, we are responsible for the infrastructure we use for operating as a department. We managed things ourselves unless when we have a full hardware crash then we get the IT teams to manage the stuffs and or check the network for us. But whenever were facing challenges, we have a sizeable IT unit to assist us. – P01"

Furthermore, P05 acknowledged that there is an IT business unit in their firm but commented on the lack of knowledge in terms of BIM. This shows that the IT business unit are not knowledgeable on the BIM tools, BIM processes and BIM skills needed to successfully implement BIM and therefore they cannot be depended upon when the firm decided to fully implement BIM.

> "Yes of course we have. But they are not familiar with Revit software, so they are already familiar with web email and those sorts of things. – P05"

Upon further discussions, P06 agreed with P01 and added that the IT business unit assist in making provision for the IT infrastructure needed to support BIM, such as the best hardware and software equipment. However, P06 reported that the management has made provision for the necessary IT infrastructure to support BIM based on the requirements provided by the employees.

> "Well, we are having an ICT department. Yes. But now, this ICT department what they do is they do not exactly know our own requirements that's for the engineers and architects they don't know what we need to do our job so what we do is because before they make any provisions for us at the office, we write out to them with our specifications, this is what we need for effectiveness and good delivery of the job. They try to provide the best equipment to suit our specification that is what they do. The equipment we are talking about the hardware and the software. – P06"

On the other hand, two firms with a low level of BIM usage reported that there is no IT manager or IT business unit. For example, the P07 statement indicates that there is currently no IT manager in the firm. However, contrary to P06 that has a sizeable IT unit, P07 has no IT unit or IT manager, and this could be because P07 has relatively lower BIM maturity level than P06 firms which has a BIM maturity level of 2. Thus, there is indication that firms with higher BIM maturity level are more likely to have IT manager (s).

> "…for now, we don't have. – P07"

Similarly, it has been agreed upon that the nature of employment has a positive influence on the firm. P04, for example, was overjoyed to reveal recent discussions within their company about hiring an IT manager on a full-time basis because it is more cost effective and convenient for their company in the long run. The IT manager is expected to manage the IT section, drawings, software upgrades and because the cost of inviting an IT professional is high, the firm decided that hiring a fulltime IT manager would reduce the cost. It is worth noting that the firms that agreed upon the benefits of having an IT manager on a full-time basis have a higher level of BIM usage. Furthermore, due to the expensiveness of hiring IT professional the firm resorted to outsourcing the IT section management to their business partners before currently considering hiring a full time IT manager. This indicates that the firms prioritise and focus on more developing relevant aspects of the firm.

> “Thank you for bringing up this question because last week we had this discussion with our partners and staff about needing somebody to employ. We have somebody on the temporary basis or part-time basis. We bring him in, and he does the services, and we pay him off. But now we are planning on bringing a full-time IT manager that will manage our IT section, our drawings, archives, software upgrades and everything so we are thinking of that, but you know it comes with a cost and those IT guys are sometimes very expensive. I say said in Nigeria, you look at the necessary part and you finish with the necessary section then you move to the other areas. but basically, right now the IT section is managed by our partners. – P04”

Furthermore, P06 highlighted the importance of skills and competency to the role of the BIM manager. P06 shared an example of a job applicant who applied for the role of architect, but after reviewing the individual credentials, an offer of a BIM manager was made due to the individual's experience and ability to train the other employees. Therefore, the firm focus shifted from recruiting an architect to recruiting a BIM manager due to the difficulty of finding applicants with BIM knowledge. Additionally, the BIM manager is also expected to train the employees on how to utilise BIM. P06 has a BIM maturity level of 2 and thus this align with the discussion around the higher BIM maturity level firms are more likely to have digital manager (i.e., BIM manager in this case).

> Yes because really it is kind of difficult to find an individual who out of their own desire trains themselves but it is an advantage when they do that at because I know of a person that went for an interview, and she was interviewing for the position of an architect of a company and when they saw from her CV that she was a BIM manager or a BIM user actually and instead of employee has an architect, they just employed her as a BIM manager in the company so she got to train the other staff in the company how to use BIM. – P06

6.2.4.3 Top Manager

Top manager support is required throughout the implementation process (Abbasnejad and Nepal, 2016). Top management must be committed, willing, and active participants in the process, allocating valuable resources to the implementation effort. The participants identified the criteria of top managers that influenced BIM adoption within their firms to include knowledge and experience, leadership and mentorship, ability to motivate employees, and lack of resistance to change. However, knowledge and experience of an individual are the source of ideas and knowledge creation of an individual and this determines the ability of an individual to achieve organisational goals (Morris & Snell, 2011). In the Nigerian SMAFs, the ability of the top manager to encourage and support his team through mentoring and willingness to learn enables an open organisational culture that supports BIM adoption and fosters the innovativeness of the employees. P11 disclosed that there is an open-door policy that allows employees to gain knowledge and learn. Furthermore, the ability of P11 to learn and transfer the knowledge to his teams/employees contributed to increasing the competence of the employees.

> “Going back to that, sometimes it becomes more challenging for me, but I like that because if there is something that I don't know I try to learn it within a few minutes and then transfer the knowledge to them and in that process, it stays in my head and I learn it as well. That is the beauty of teaching something you've learn – P11”.

Similarly, the experience and knowledge of a top manager are important considerations and a requisite during the employment process within their firms. P01 (BIM maturity level 2 firm) reported that their firm is gradually emphasising on an individual knowledge and skill of BIM during the recruitment process. Therefore, individual’s BIM knowledge and skills are crucial considerations within firms with higher BIM maturity level.

> “So, I will answer this based on the last interview that you had. When I conducted an interview to hire an architect, I was looking particularly for someone with a basic skill in BIM even if it is not full information knowledge but at least he should be able to do a basic model and add information and use Revit efficiently. So, it is gradually becoming a requirement in every other department – P01”.

6.2.5 Organisational Capability Analysis

The subordinate themes that are related to organisational capability are management support, IT infrastructure, and policy and process as shown in Figure 6.1. However, in the subsequent sections, the analysis of the organisational capability is presented.

6.2.5.1 Management Support

Management support is important for adopting BIM successfully and can serve as a catalyst for innovation and knowledge sharing which are essential to developing competitive advantage within the firm. Training (i.e., formal and informal training) has been identified by 10 of 17 participants as the main support that management provide in their firms. Formal training is considered as the training provided through organising seminars, workshops or in-house training programmes, whilst informal training is considered as training from colleagues or mentors such as top managers, on the job training, and individual learning through online platforms or individual research. P01 mentioned that the firms provide seminars and invite international companies to enable the employees to gain up-to-date knowledge. This can sometimes be a channel of knowledge acquisition also.

> “The company also invites most of the seminars to the international companies on a global scale, so you are up to date as to what is happening to other clients and things like that. – P01”

Also, there is discussion around the provision of in-house training by 6 of 17 participants where the firm invites a trainer to the firm to deliver training for the employees. For example, P01 disclosed that their firm usually brings an in-house trainer on specific aspects. This could be learning software or how to share information more efficiently between co-workers during a project. However, since the training does not cover all the aspect of BIM process, the employees tend to learn aspects that are not cover within the training themselves which means that the employees are willing to learn themselves.

> “we also do something called in house training where I can look up a particular aspect of what I think is happening now and try to learn it on my own – P01”.

Similarly, P02 disclosed that their firm also invites a resource person that provide inhouse training in their firm. These training is usually focused on specific aspects such as how to manage and coordinate design information in a BIM environment.

> “So, what do you normally do if you get a resource person to come and train in the office. – P02”

Upon further discussion with P02, he disclosed the process of adoption of new technology such as BIM within their firm. P02 affirmed that the individual that identifies a potential BIM technology that would be beneficial to the firm is usually assigned to learn the technology and then tasked to demonstrate to co-workers how to utilise the technology. This means that there would be an expectation of organisational learning between the co-workers. Furthermore, the firm has demonstrated their ability to manage resources with regards to providing the software license and training of employees. The firm buys a single license for an employee to learn and evaluate BIM tools and process. The employee then demonstrated the technology and process to the colleagues and then the firm purchase subsequent license for the software gradually.

> “They will get the software and let the person that brought it use it or go and learn from the other office then he will come and show others. From there, we will be buying it in parts until everybody has it. – P02”

Furthermore, P14 stated that their firm organise workshops and seminars to educate staff and employees on BIM. Therefore, this shows that their firm’s management are keen to developing the BIM competence of the employees through organising and investing on BIM workshops and seminars.

> “We have been recently trying to organise some workshops and seminars to educate our staffs and employees and BIM and get more information about that. – P14”

Similarly, P04 highlighted the importance of regular training within the Nigerian SMAFs. In addition to the regular training, annual and bi-annual training is conducted especially after the annual leave holiday which serves as a refresher for the employees. This will keep the employees updated on current BIM processes and tools.

> “There was a time that we are back on holidays training's and once or twice – P04”.

Additionally, P06 affirmed that there is the provision of training by their firms from time to time on CAD software. However, the training provided is not extensive but more like a refresher/brush up on the existing knowledge. It is worth noting that both P04 and P06 (i.e., BIM maturity level 2 firms) highlighted the importance of providing regular BIM training on employees BIM competency development.

> “But to an extent the train us from time to time. there are companies that do that, train their staff for use of this computer aided design is just that. we do not get extensive training.it is usually just the basics like a brush-up. – P06”

On the other hand, lower BIM maturity level firms such as P07 disclosed that there is little or no support from the management with regards to formal training. However, there are access to informal training through various channels such as peers and colleagues from school (i.e., educational institutions such as universities). Further explanation was disclosed on how the management support or rather approval for an individual that wishes to adopt new process or experiment on new tools with the condition that the individual can achieve the standard result that is expected in the firm. This also indicates a bottom-top decision approach where the employee decides to adopt BIM and later persuade the management. However, without the management support with training, the employee would have to rely on informal training which requires a lot of self-motivation and willingness to learn.

> “Actually, for now no they don't. Only informal training […] They are training provided and they are colleagues from school that give use training. There are a lot of ways […] If an individual decides to start using a new software or a work process it is something that the organisation will accept provided it can be used to achieve the standard of the company. – P07”

Indications about individual characteristics and attitude to the success of training within an organisation have been highlighted by 3 of 17 participants. As P04 explained, the individuals most required in their firm are those with the ability to learn and are ready to improve. According to the statement below, even though they may not be with the company forever, they still invest in training and equipping employees with BIM knowledge.

> “We look for people that will be loyal, people that are ready to learn, people that are ready to improve and we usually get the younger minds that are always ready to learn who are full of energy. We always tell them that they are helping themselves for learning because when we train them and give them this knowledge. In the long run they might not be with the company forever, but they will have the skills and that is the best asset we can give to them. – P04”

In addition, 3 of 17 participants mention that the lack of funds is a possible rationale for why some of the firms do not support formal training. However, additional to the cost of formal training, the expense of IT/BIM manager is also a key barrier of BIM adoption as discussed in the previous section (see section 6.2.4.2). For example, P03 has identified training as the most important factor to consider when adopting BIM but has also highlighted that training requires funds to execute because some of the formal training is conducted through the organization of seminars.

> “Cost is one of the major factors and then training as well. And since training requires you to organise some seminars and so on therefore it required some funds as well. – P03”

With regards to incentives, 3 of 17 participants mentioned that the management only supported the staff with training and no further commitment or incentives were offered. However, staff continues to use BIM technology and processes because of the benefits, such as the ease it provided in the delivery of their projects, the management of information capability, and the ability to identify clashes before presenting the final work. For example, P01 reiterated that there is no incentive that the management offer in addition to the personal benefits of using BIM technology. Reflecting on this, it is evident that, although there is management support in the form of training for the higher BIM level firms, there are still contradictory reports on the provision of incentives as well. Nonetheless, employees within SMAFs that encourage innovation are keen to utilise BIM for their personal/professional development.

> “apart from the training that you get for using it there is no incentive offered for using it. You just get the ease of doing your work or the confidence in whatever work you are putting on. Such as putting enough information in whatever you are giving out and looking at your work more critically to identify where clashes are and being more confident in approaching other departments with whatever you are presenting. Apart from this there is no other incentive that you gain about from your personal gain. – P01”

Contrary to P01, P03 reported that there are a few motivations in terms of incentives from the firms. Another example was shared by P03 on a recent project that utilised the BIM process in the design stage. The firm realised the benefits of the BIM process during the construction phase because of the effort made during the design stage and saved a lot of money. This encouraged the management to support the employees that worked on the project with incentives such as increment in financial allowance. Therefore, firms that realise financial BIM benefits are likely to provide financial incentives to their employees to encourage other employees to participate in BIM projects. Thus, incentivisation can also serve as a strategy to persuade the employees to participate in BIM project.

> “I will say that there are a few incentives and motivations to use BIM. Yes, for example there is a recent design that was done in one of our projects and the architect that led the design was able to incorporate BIM in his design. After doing that, the company executed that Project, and the project was completed it little challenges especially the clash detection where avoided which led the company to save a lot of money, so the company decided to what the architect which got some incentive as well. – P03”

Furthermore, 13 of 17 participants agreed upon utilising some form of incentives as motivation to persuade/encourage their staff to comply with company policy. For example, P04 reported that incentives are given to employees from time to time as a reward for splendidly completing their work such as design. This is additional to their salary to motivate them for their efforts. Further evidence of verbal encouragement was highlighted among the techniques the firm uses in motivating their employees. Furthermore, the ability of the top management to motivate and encourage the team is important to positively change the mindset of the employee. However, the top management persuade the employee through sharing BIM benefits testimonies.

> “So normally what we do is we use psychology for them of course there are incentives from time to time especially apart from their salary whenever they finish a good design, we reward them for that, and we always encourage them and give them motivational words and appreciate the effort. so, this is someone the psychology we use for them and then we always tell them that they are not

> doing it's just for the company but for themselves because we are training you and you are having the skills and if you get the skills nobody can take it away from you. This is some of the technique used to push them to do more. so, we are always leveraging on the fact that we are benefiting from your work and you are also benefiting from our training. – P04"

6.2.5.2 IT Infrastructure

IT infrastructure such as software, hardware, network, and maintenance of facilities have been identified to be crucial to BIM adoption within the Nigerian SMAFs by the participants. P01 reported that IT infrastructure such as hardware, network backup systems, and cloud-based storage system are among the key requirements needed to support the firms' shift towards BIM adoption. Furthermore, the firm's decision to invest in IT infrastructure was influenced by the apparent importance of BIM within the firm. This was demonstrated by employees with relatively higher BIM competence through demonstrating to their peers the process and benefits of using BIM.

> "…It was not there a few years ago but the company made the conscious effort to provide all the infrastructure required. […] some of us have the capacity to adopt and train our fellow colleagues on how to use building information modelling and they saw the importance of using it, the company was willing to upgrade the infrastructure for us and then they got new computers, new network backup system, central storage for our files and drive systems and things like that such as cloud-based storage system. – P01"

Additionally, firms that provided basic infrastructure such as internet, software, cloud storage to their employees are at BIM maturity Level 2 while firms that did not acknowledge the provision of basic infrastructure to their employees, are at lower BIM maturity level 1 or lower. Therefore, there is an indication that the provision of basic infrastructure has a relationship to the BIM maturity level of the firms within the Nigerian SMAFs. However, P03 reported that the cost of IT infrastructure such as BIM software is expensive, and that is a challenge for most of the firms. Thus, the reason why some of the firms are not investing in IT infrastructure to support the BIM adoption within the Nigerian SMAFs.

> "The cost of the BIM software is somehow expensive to acquire the software that is used for the BIM so I can see the cost is also a challenge that we have been facing – P03".

Considering the discussion around cost related challenges of BIM adoption, other cost aside from the IT infrastructure such as cost of IT/BIM manager and cost of training employees needs to be considered as well as highlighted in the previous section (see section 6.2.4.2 and section 6.2.5.1).

6.2.5.3 Policy and Process

Policies serve as a guideline and set of rules that every individual is required to adhere to within the firm and, as such, most firms develop policies to further their BIM mandates and achieve their BIM adoption targets/goals. For example, P03 disclosed that their firm has a policy that encourages sharing information within the organisation digitally because the firm has a vision of becoming paperless. The vision towards paperless business within the firm served as a facilitator for the adoption of BIM. Moreover, adopting BIM facilitated collaboration and management of information within the firm thereby reducing the amount of hard copy design information shared and archived for future reference within the firm. This also indicated that the firm develop policies that encourage to the employees retain BIM process and this has been a strategy for confirmation stage within BIM adoption process as previously discussed (see section 6.2.3.5)

> "So due to our policy of trying to go paperless we are using Digital copy mostly. – P03" … "So, you've created different policy to make sure that BIM is being adopted – P03".

Contrary to P03, P13 mentioned that there is no policy or standard process to deliver a project in place. The indicates that their firm prioritise the delivery of the project over the process the project is delivered. However, employees have indicated that among the benefits that BIM provide is ease of work and time saving during project deliver (see section 6.2.2.2). Therefore, there is still a tendency for the employees to adopt BIM due to its benefit such as ease of workflow which enables them to complete their task more efficiently.

> "No, we don't have that there is no specification however you deliver a work it's fine as long as you deliver. – P13"

In the context of the Nigerian SMAFs, 5 of 17 participants highlighted that the firm has a policy that mandates the employees to consistently attend events such as workshops and seminars for upskilling and developing the employees BIM knowledge. For example, P01 reported that every member in their department is mandated to attend a workshop and, therefore, the firm organizes events, workshops, and seminars consistently.

> "For us the company makes it mandatory to attend a workshop. So, we do have events, workshops, seminars consistently and every member of the department goes to. – P01"

Furthermore, both external and in-house training channels are utilised within the Nigerian SMAFs. As such, the firms with BIM maturity level 2 reported that the process of training is in-house or via external training programmes where few employees are trained and expected to transfer the BIM knowledge among their peers or colleagues within the firm. Additionally, P10 mentioned that there is a policy enabling at least four employees from different section within the business to attend annual training on how to use BIM tools. This indicates that policies can be utilised the support the upskilling of employees. Thus, making it easier for the employees to understand and apply BIM knowledge to their current workflow.

> “Once a year at least three or 4 people go for a training from different sections but then the rest of the employees train individually. – P10”

Additionally, P04 mentioned the importance of an open-door policy within the organisation to enable employees to learn and create new knowledge. Therefore, this suggests that the flexibility in policy and process within a firm influences the company's working environment and individual competence. For example, P05 stated that the management does not have a rigid policy on the process by which an individual delivers their task, however, the firm has a policy that rewards an individual for completing their task. Therefore, the employee competes to complete their assignment and receive a financial incentive that is additional to their salary. This shows that firms within the Nigerian SMAFs are utilising policies to support incentivisation and encourage the employees to be more productive and deliver their task.

> “because if it is up to the management, they will force everyone to use the Revit. […] So, like I said earlier after completion of every drawing you get set in percent which is not part of your salary. […] and the companies are always like here you have done something for the company so let us give you something as well so that you'll feel at home.” – P05

6.2.5.4 Funding

It has been observed that the lack of sufficient funding is one of the challenges of BIM adoption within Nigerian SMAFs. The cost of infrastructure such as hardware, software licence and network, the cost of acquiring knowledge and training personnel are among the focal points of discussion by the participants. For example, *P03* pointed out that the main challenge in their firm was the cost of the BIM software and training because training through organising seminars and workshops requires funds.

> “The cost of the BIM software is somehow expensive to acquire the software that is used for the BIM so I can see the cost is also a challenge that we have been facing” … “That is one of the major factors and then training as well. And since training requires you to organise some seminars and so on therefore it required some funds as well. – P03”

Similarly, P04 suggested that the software vendors should have some consideration for developing countries, especially Africa. P04's opinion is that reducing the cost of the software would encourage firms to purchase the license, especially in Africa. Furthermore, P04 explained that there is no assurance of regular job throughout the year and the expense of running the firm might not allow for the purchase of a license. Therefore, most firms revert to using a student license or illegal software license. However, issues concerning the use of fake licenses were reported to limit the users from utilising the full potential of the BIM tools.

> “Reducing the cost would allow firms to purchase, especially in Africa. $2,500 is a lot of money and for you to purchase a subscription for a year. You might not get a job for 6 months that will cover for the licence and you must pay salaries and office expenses. So, most of the software that we are using is cracked or student licence that is free from the of Autodesk. But the demerit is that you are not getting the full advantage of the software because there are limitations as to what you can access. – P04

Considering the above, P06 not only corroborated that most firms use fake licenced software due to the high cost of the software license, but also highlighted the demerit of using cracked versions limiting the firm fully utilising the BIM tools. Furthermore, P06 added that using a cracked version of BIM tools is not suitable for BIM managers because the cracked version has restrictions on connecting to online resources that support collaboration with multiple users. Therefore, firms would still have to purchase the software license to gain the full benefits of the BIM tools. However, firms that have higher BIM maturity level and investment funds due to their size or number of jobs/clients are more likely to purchase the software license because the firms with higher BIM maturity level understand the value of BIM and have access to the funds needed to invest in BIM.

> “to get the correct BIM cost is expensive and it is only the well-established firms that can afford it because of the price and then usually the software that we use here are cracked versions. So, with the cracked version you cannot exactly unlock the access and you cannot be a BIM manager if you are using the crack version, so you will have to buy it and get the licence good and what not. – P06”

In addition to the suggestions that vendors should provide a special consideration for Africa, participants have also suggested that increasing the number of individuals that can have access to a license might encourage the purchase and use of BIM tools within Nigerian SMAFs. For example, while P06 acknowledged the high cost of a license, P06 reported although BIM tools such Revit have multiple seat license, increasing the number of individuals that can access the tools will encourage more people to use the BIM tools. This shows that there is a maximum number of individuals that can access the tools which is low. However, P04 earlier stated that a license can cost up to $2500 which is on the high side for most of the Nigerian SMAFs. Therefore, for firms that are just starting, this is expensive since there are other expenses that are needed to run the business. Thus, these are the reason why the Nigerian SMAFs prioritise and consider the benefits before fully investing in BIM technologies.

> "So even if it is expensive instead of having 10 people to a licence you can have like 100 people to a licence. That way they will be more people using the software because it has as more advantages than disadvantages – P06".

6.2.6 Environmental Control Analysis

The subordinate themes that are related to environmental control are internal pressure and external pressure as shown in Figure 6.1. However, in the subsequent sections, the analysis of the environmental control is presented.

6.2.6.1 Internal Pressure

The internal pressure such as maintain reputation and good image because of interaction between team members or employees has been highlighted to foster BIM usage. For example, P05 reported that the pressure from colleagues that used BIM tools was a catalyst for the non-BIM tool users to learn BIM tools such as Revit in order not to feel inferior or maintain their image in front of other colleagues.

> "If a colleague learns something new that can ease the process of designing, he can show you how to do it, but you will have to practice it yourself to become good. Next time you would want to learn something else to make sure that you are ahead of your colleagues. Some of them had to learn Revit because most of our partners use that and you do not want to always ask for AutoCAD file. – P05"

Furthermore, P01 acknowledged that there is pressure within the firm because they make sure everybody is part of the team and carried along. P01 further explained that even those that are not directly part of the design team have basic knowledge of the BIM tools such as navigation and visualising of the information embedded in the model. However, the pressures are eased by people within the team that are willing to teach other members how to use the basic tools, i.e., through informal training. In addition, P01 disclosed that the team members that are willing to teach other members cannot be consistent and maintained because they have another task and project to deliver. This means that they must speak with their manager to assign them dedicated time to deliver in-house training to avoid constant interruption from their colleagues and disruption to their other tasks and project deliverables.

> "Yes, within my company, certainly so we will have that pressure because we try to make sure that everybody that is part of the team knows every software that every other person is using. At least the fundamentals […] how to navigate

> basic Revit to spin around the models, view footprint and linking buildings with. The masterplan and things like that. So, there is a pressure in that, but that pressure is also eased by people within your team willing to teach you how to use yourself. That is where the in-house training comes in. so we constantly teach ourselves how to use the software […] and they can meet […] their manager and ask for 2 hours to train their colleagues so that they do not keep coming to other colleagues and interrupting them while working on other projects. – P01"

6.2.6.2 External Pressure

The idea of external pressure refers to the pressure from the external environment such as the firm's relationship with government, regulatory body, educational institutions, business partners which have influence BIM adoption within the Nigerian SMAFs. The external pressure may be related to the firm's network resources resulting from interactions with the business environment. In the context of Nigeria, external pressures identified by the participant include the pressures from interacting with external business partners (including clients), government and regulatory bodies, professional bodies, and the tech marketplace (the environment).

6.2.6.2.1 Business Partners and Client Demands

Business partners (i.e., local, and international business partners) can serve as external pressure that facilitates BIM adoption with the Nigeria SMAFs. Three of the seventeen participants agreed on the impact of business partners on BIM adoption. P01 reported that a collaborative project between their firm, Nigerian ministry of works and a German company to develop building energy codes for Nigeria required extensive BIM knowledge. However, the German company had prior experience on collaborative BIM project while P01's firm had little experience on collaborative BIM projects. Therefore, the firm needed to quickly upskill their BIM knowledge to meet up with the project requirement and avoid losing the contract. This indicates that international business partners such as the German company encouraged their firm to develop their BIM knowledge to effectively complete the project. Furthermore, the experience of this project led to the firm's decision to fully adopt BIM in all their subsequent projects.

> "The only time that I felt a bit of external pressure is working with federal ministry of works and international body from Germany which are working on building energy codes for Nigeria. so be walked with them on a few of our project and we were showing them how we calculate energy efficiency and how we try to achieve energy efficiency and integrate them to our project, and you can tell that they had an extensive knowledge of BIM and they felt that full

> implementation of building information modelling should be part of every design and if you are trying to use energy rating in your building the use of building information modelling should be fundamental to you. I think that is the only time I felt some form of pressure working with an external partner telling us that you're doing the right thing, but you're supposed to be including BIM in the process. – P01"

Additionally, discussion surrounding the influence of business partners, particularly large firms, has been highlighted by 4 of 17 participants. P02 reported that, the larger firms influence the choice of BIM adoption within the Nigerian SMAFs because the larger firms have a contractual requirement on the tools and process that is needed for their nature of projects. Therefore, for the Nigerian SMAFs to align with the larger firm's project requirements, they have to demonstrate their BIM capability to win more work and build their business relationships.

> "Yes, because now… if the big firms are given a job and they say that this is what they are using, you don't have a choice because you are looking for work. You also must go and learn it and adopt to their system. – P02"

Similarly, local business partners have influence and exert pressure on their counterpart partners. For example, P04 mentioned that, although peer pressure from colleagues encourages the employees to upskill their BIM competency level, the employees also perceive external pressure from business partners that have higher BIM competency when collaborating on a project. Similarly, the firms challenge themselves to upgrade their BIM capability to compete with their partners that are much larger firms. Furthermore, P04 mentioned that social media as a communication channel enable their firm to evaluate the level of BIM activity of their partners in different geographic locations. From the evaluation, the firms concluded that some of their partners are ahead in their digital delivery process, BIM capability and maturity. This motivates the firms to further develop their BIM capabilities.

> "The pressure is from the partners. We always challenge yourself to upgrade and meet up deadline. To be honest they are not much pressure externally because at the level that we are now in the company. Though it is small company, even the bigger firms or our immediate competing partners cannot compete with us at the level we are. The pressure is usually from social media we see guys from Lagos and Abuja sometimes they are doing much better presentation so that is the real pressure that we have, and we also tried to upgrade on capacity. Especially this Lagos guys in the south and they are doing well with the Revit and BIM process to be honest. – P04"

Additionally, P06 reported that although BIM designs are not a requirement for the building approval process, having a BIM design is additional financial benefit when presented to some clients. This indicates that the SMAFs are adhering to BIM process due to the identified value BIM (see section 6.2.2.2).

> “Yes, we have standards because you must submit your full working drawing, but I don't think they ever requested for 3D. 3Ds are usually a plus for when you are selling it to your client but not for approval. For approval, the Mostly require 2D drawings like 2D detailed drawings of everything that is what they require. – P06”

6.2.6.2.2 Market Place

P06 identified financial benefits to be the main motivational factor for BIM. However, this is associated with the capitalist nature of society. An example was that firms are motivated to adopt BIM when there is evidence that their colleagues within the same marketplace using BIM are having a competitive advantage through securing more contracts and realising more financial benefits. This encourages firms to learn and integrate BIM within their firms. Otherwise, if there is no evidence of such financial benefit, then there is a lower chance of adopting the BIM process. In addition to the financial benefit of BIM adoption within the Nigerian SMAFs, P06 highlighted the benefits of having a seamless workflow through a BIM model that serves as a central repository for the project stakeholders to share information during a project. This indicates that although the initial reason to adopt BIM is due to the potential financial benefits, other non-financial benefits such as the value derived from the BIM model is realised within the Nigerian SMAFs following the adoption of BIM.

> “It depends usually what motivates people is, we live in a capitalist society so what motivates people is always money and you know the thing is if my colleague from another company is using BIM and I see that he is getting more contract than I am I will be motivated by that. I will also go a learn BIM just so that I too will get contracts from that. But if we are still rolling on the same level with or without BIM, we are on the same level then the only motivation for me now is because it is effective, and it just makes you have a seamless work. and who does not like seamlessness. everybody wants something easy. I just want to sit in front of my computer and see that my mechanical and structural drawings have all the information they need to have as soon as I want them not when somebody is sitting back and saying that I have not seen your email and I have been waiting for your email or something like that. so that is it. – P06”

6.2.6.2.3 Professional and Regulatory bodies

In Nigeria, the submission requirements needed for approval by the board include a hardcopy and a softcopy at the federal level and only hard copies at the state level. P04 associated this submission requirement with the lack of an organised data system and accused the government with lack of interest in BIM. Furthermore, P04 reported that the lack of government interest in BIM can be associated to the lack of understanding of BIM benefits by the government and therefore the reason why the government are not pushing the adoption of BIM throughout the Nigerian building sector. This indicates that government awareness of value that BIM can provide might increase the government interest and lead to government encouragement to adopt BIM in Nigerian building sector.

> “in the Federal Capital Territory, you submit put the soft and the hard copy but in the other States the only take hard copies because they don't have an organised data system. The minimum level of acceptance is 2D drawings but when you had a 3D design it is an added advantage, but 3D is not a requirement. so that is why I was saying earlier about the government it is not really into BIM or they don't really know what it is, so they are not pushing for it. but if you submit the 3D, they will look at it and you will get a better understanding and it will pass the approval. – P04”

Furthermore, P04 opined that the only way for BIM adoption would be successful within the Nigerian building industry is to mandate BIM design to be a requirement for the approval and construction process.

> “the only way you can adopt him in Nigeria is for the government to be serious and put it as part of his approval process and part of the construction process because that is the only language that the professionals will understand. – P04”

On the other hand, professional bodies are identified to occupy a leadership role in determining the BIM tools that are appropriate for adopting BIM through their affiliated learning institutions. For example, P05 acknowledged the potential influence of the professional body and commented that there are several professional bodies within the industry that should be able to agree upon the BIM authoring tools that can be incorporated into the learning institutions. This would assist in providing graduates that are proficient in BIM tools such as Revit and create harmony within the practice. Additionally, this can increase the number of BIM proficient graduates that can be employed into the industry.

> “… they just have to come together and agree on a software and from there they can push it to get Academy and before you graduate you must attain a certain level of proficiency in certain software. Like only the architects started Revit in school […] so, there is no harmony. – P05”

Similarly, participants are of the perception that the professional bodies have a role to play on putting pressure to the government with regards to the issue of BIM adoption in Nigerian. Furthermore, 5 of 17 participants have expressed that the professional bodies are required to influence the government to provide the necessary awareness as to the value of BIM and the requirements needed to support the drive for BIM within the industry. P06 mentioned that if professional bodies could demonstrate the benefits and value of BIM to both Nigerian and global building sector, the government would provide special considerations and requirements to support organisations adopt BIM.

> “I think the professional body is the one that will convince the government because the government is just like management, they don't know what it entails they don't know what you need […]so they can influence the government into making these things available for us… – P06”.

P07 reported that there is no pressure to adopt BIM designs because the standard requirements of the regulatory bodies do not require BIM only 2D designs and hardcopies occasionally.

> “Yes, like to have like a standard. so usually give them in pdf format not .dwg. or sometimes printed. – P07”

Additionally, P06 stated that presenting 3D drawings has an added advantage in the approval process because it makes it easier for the board to visualise the submitted designs although it is not a requirement. However, with a BIM model, 3D designs can be extracted and presented to the regulatory body leverage the added benefit. Hence, the firms that adopted BIM tend to benefit from the model during the approval process. This also indicates that although there is no requirement for BIM designs, the firms adhere to BIM design process.

> “Yes, we have standards because you must submit your full working drawing, but I don't think they ever requested for 3D. 3Ds are usually a plus for when you are selling it to your client but not for approval. – P06”

6.2.6.2.4 Educational Systems

Educational learning institutions are identified by the participants as a channel that could be utilised in increasing BIM awareness, disseminating BIM knowledge, and training future industry professionals. For example, P01 acknowledged that the educational system provided them with the basic knowledge and skills of digital design tools and, therefore, the educational system has an influence on the knowledge they acquire in their early career stages.

> “Yes, the educational system has influence on what I was taught or at least the basics of what I was taught on Revit. – P01”

Furthermore, the digital tool that was predominantly taught in the learning institutions during their university days was Revit although it was looked at as a generic 3D modelling tool like SketchUp and not from the perspective of a BIM authoring tool. Therefore, with an improvement to the educational institutions curriculum, the institutions can be used as a channel to provide the industry with future professionals that are proficient in the necessary skills needed to use BIM tools and technologies. Additionally, having prior knowledge of tool made it easier for employees to understand and apply it in their current workflow when in was introduced as a BIM tool in their firms. Furthermore, P05 reported that educational institutions such as the universities can collaborate with the industry and provide BIM training to the professionals since the educational institution already have a track record of teaching Revit. This indicates that there are BIM tools such as Revit taught in the university but there is need to review the curriculum to align with BIM techniques and processes.

> "So, I think the university can help people to learn BIM through training young professionals or collaborating with the industry. I think myself and all my colleague learn to use Revit in our 400 level, and I think about 90% of my colleagues are still there using Revit. – P05"

Similarly, P04 suggested that the educational system needs to revise their curriculum to meet the current global challenges and industry requirements such as the need increase efficiency in construction project delivery which are achievable using BIM. However, contrary to P01 and P05 that acknowledged the importance of the educational institution in learning the basics of design digital tools, P04 reported that the educational system is in a poor state and currently provides little value for prospective industry employees when it comes to the latest trends such as BIM. Therefore, there is need to improve and review the current curriculum of the educational institution.

> "So, I always tell them that you don't have to wait for anybody else you at this era. we go to school to learn distance but now to be honest with you the school system is teaching things that sometimes we don't even need. the importance of school is that at least you might have this social understanding of different cultures and build relationship and networks … – P04".

Additionally, P04 reported that BIM is not included in the curriculum of the universities and the lecturers are not encouraging the students to utilise BIM because they are not knowledgeable on the subject and tools. However, the educational system is crucial to developing the intellectual capital and knowledge base required for the next generation of professionals and, as such, there is a need for careful consideration of what the next generation is currently learning and what they need to be learning. The knowledge impacted on students directly affects the level of expertise of individuals in the industry. Participants have identified challenges with regards to the individual's knowledge during recruitment and argued that the educational system can play a greater role in training entry level candidates with the required. Therefore, a collaboration between the industry and educational institutions would enable the professionals and academics to upskill/ reskill themselves. This would increase the overall BIM competency of professionals within the industry.

> “I don't know for the UK because I have not started in the UK, but I hope someday I would. From what I have heard the UK have a better system than what is available in Africa in Nigeria to be honest with you in our own schools there are universities that are not accepting designs and prefer and sketches which is... I do not even know what to say. They do not have BIM in their curriculum and staff are not encouraging the students to learn such systems which is very bad because some of the staff do not know how to use the or software like that because BIM is much more than a software I believe. So, they do not know the whole process, but few schools are improving and changing their curriculum but overall, we need to do better. – P04”

Additionally, P07 mentioned that BIM designs should not only be mandated as a requirement for building approvals by local authorities such as development control but professional bodies and learning institutions should intensify the provision of BIM related training. This would increase the rate of professional development in the industry and give more professionals access to BIM related training. Additionally, P07 added that BIM designs should be encouraged and allowed in universities while hand sketches should be completely abolished during students' presentations. This indicates that there is need to improve the current curriculum within the Nigerian educational institutions to accommodate BIM related curriculum. This would enable future professionals to develop interest and be familiar with BIM.

> “The professional bodies and learning institutions should invest more on BIM training. They should adopt the use of BIM throughout the division of their training and project delivery. So let them completely abolish the use of hand sketches for presentation and let the students be presenting BIM designs. That is at the institutional level and local authorities like development control in Abuja should make it mandatory to present BIM design for their approval. I think that's how my points for now. – P07”

6.2.6.2.5 Standards

Standards have been an important factor in ensuring BIM adoption. In Nigeria, there are standards that the construction industry adheres to. However, there is no documentation demonstrating that BIM standards are followed in Nigeria. All the participants have acknowledged the availability of standards in Nigeria but denied that there are any BIM standards or guidelines. For example, P01 mentioned that most firms adhere to international standards/guidelines such as LEEDs certification, although it is not a requirement by the Nigerian government.

> “Some of us adhere to LEEDS Certification and other standards and we strive to adhere to those international standards but from the national or Nigeria side of it is not required by the government for any accreditation. I am not aware of any international standards that is a requirement. – P01”

Similarly, P02 denied any awareness of BIM related standards such as EN BS ISO19650. However, there was also mention of awareness of other international standards such as British Standard (BS) codes. Furthermore, P02 disclosed that there is also an indication of a new code proposal by the NIA and ARCON related to the Fire code. However, a proposal for BIM standards specific to Nigeria should be presented through the professional bodies such as NIA and ARCON to attain full support of the professional bodies.

> “No BIM standards for now [...] We use BS code. British standards code. But of recent, I know NIA is proposing Nigerian Code but what they are dealing with is mainly fire code […] we have building codes […] must sell this to (the NIA) ARCON because they will be the one. If new things are coming and you do not go through them, it will be like you are trying to go through the back door and they will condemn it. – P02”

6.2.6.2.6 Government

The government are not only the major clients of the Nigerian construction industry but also the major influencer on the practices within the industry. Currently, there is little or no interest in BIM adoption by the Nigerian government at large. For example, P04 associated the lack of BIM interest of the government with their lack of awareness and hence the reason why there is not much support or encouragement by the government.

> “… so that's why I was saying earlier about the government it's not really into BIM or they don't really know what it is, so they are not pushing for it… – P04”.

The perspective/perception of the participants is aligned with the belief that although there is little awareness of BIM within the learning institutions, the regulatory bodies and government need to put more efforts towards encouraging the firms to present BIM designs for approval. The participants also highlighted that there is no BIM requirement from the local authorities to approve a design or BIM mandate from the government to push BIM adoption within the industry. Furthermore, emphasis was made on the influence of the government to embrace BIM because the professionals are keen to follow the guidelines and regulations of the government particularly when that would win them more contract.

> “to be honest the government are not into BIM here. At least there is little adoption of BIM in schools now, but their regulatory bodies and the government need to do more on this aspect especially the approval body. So that they will encourage firms to encourage firms to present BIM design but there is no current regulation now or any law that push for adoption in Nigeria there is none. So, whatever you present is what is the accept. when government comes in and encourage or put it among the processes

> requirements for getting approval for any building development in Nigeria, that is only when people professionals and companies will be alerted and see the need for the adoption of the BIM process. Almost everything in Nigeria deals with government. It is only the government that can encourage that, and the approval bodies can push such processes. if they like it everybody will embrace it. – P04"

Although there is no requirement, the firms are adhering to BIM processes and utilising the tools. For example, P09 stated that although their firm adheres to BIM processes in their designs from an early stage, although it is not a requirement but a benefit to the firm when engaging with clients and submitting approval documents.

> "our organisation utilises BIM from an early design stage. For example, we use Revit software to give the clients sketches so that they can understand the concept and it is easier for us to have the 3D and other designs in a single file. In fact, when we are looking for approval, we submit the 3D because it is added advantage to us. It is not a requirement, but it is a plus for use. – P09"

Similarly, P01 reported that, although BIM is not a requirement, the ministry of works is currently working towards nationwide implementation of BIM designs for energy efficiency in addition to the development control codes and national building codes. This indicates that the Nigerian government parastatal are also adhering to BIM processes though it is not a requirement for approvals.

> "Sincerely no I don't think they do the only one that I know of currently that are actually looking at the use of BIM is building energy efficiency which the ministry of works is trying to implement nationwide but before that what we have is the development control codes and then the national building code which it tells you about basically renovation requirement and things like that at. But none of them pushes it that the drawings you need to show for approvals and need to go through the process of BIM. – P01"

Furthermore, P01 suggested that a legislative backing or intervention from the government would encourage a wider adoption of BIM within the Nigerian SMAFs and the nation. This further confirms the role and importance of the government as a medium to push BIM adoption within the industry.

> "Well, I think it needs more support from the government side through a legislative backing some sort of intervention or some government intervention. – P01"

Similarly, P04 opined that the Nigerian government's role is crucial, and a starting point is incorporating BIM into the requirements of the approval process. P04 strongly believes that making BIM mandatory in the approval process would result in an increase in BIM adoption within Nigerian SMAFs.

> "the only way you can adopt him in Nigeria is for the government to be serious and put it as part of his approval process and part of the construction process

> because that is the only language that the professionals will understand. – P04" … "But if the government makes it part of the process everybody will adopt it. People will travel to other places just acquire the skills. – P04"

6.2.6.2.7 Client Demand

Participants have highlighted client demand to be a significant factor when considering the approach to use in project delivery. Therefore, this has an influence on Nigerian SMAFs decision for BIM adoption. For example, although the clients can be larger companies, government, or private investors, *P17* disclosed that the choice of adopting some level BIM process in a project depends on the client (in this case the larger firms). However, further discussions show that the ability to adopt and comply with their requirements fosters work relationships and hence, the SMAFs strive to learn and adopt the required process.

> "Yes, because now… if the big firms are given a job and they say that this is what they are using, you don't have a choice because you are looking for work. You also must go and learn it and adopt to their system. – P17"

6.2.7 Technological Quality Analysis

The subordinate themes that are related to technology quality are relative advantage, complexity, and compatibility as shown in Figure 6.1. However, in the subsequent sections, the analysis of the technological quality is presented.

6.2.7.1 Relative Advantage

Relative advantage is the degree to which an innovation is considered to be superior to the concept it replaces (see section 3.4.4.3). The extent of relative advantage is often reflected in economic importance. The participants identified relative advantage to be an important motivation towards BIM adoption within Nigerian SMAFs. Among the various components discussed under the relative advantage concepts in the Nigerian context are perceived usefulness or benefits, competitive edge, performance expectancy, comparative advantages, user satisfaction and facilitating conditions. For example, *P14* (BIM maturity level 1 firm) acknowledged that BIM has several advantages, including enhanced productivity, while P02 (BIM maturity level 0 firm), although not a BIM user, mentioned that BIM adoption is likely going to improve when the firms recognise the tangible benefits associated to BIM.

> "BIM has a lot of advantages include enhanced productivity during project delivery. – P14"

Furthermore, P02 disclosed that their firm's transition to CAD was dependent on the practical benefits it brought to their firm. Therefore, the relative advantage of BIM over the current practices within the firm is considered as a motivating factor that would influence the firms to adopt BIM.

> “yes, but people need to see it working and see the advantages before they can go for that. Like there was a time when we are using power draw. They call it power draw a software. In my office, I have to convince them to change to AutoCAD. And when they saw what AutoCAD was bringing, they now changed completely. – P02”

Additionally, participants such as P03 claimed that globalisation and information integration to BIM within their firms provide them with a competitive edge and better performance over their counterparts.

> “I believe due to the globalisation of the world now on them the way things are changing, and the information is becoming vital and data as well, incorporating BIM within our organisation will give us an edge over other companies which will make a company to perform better and to compete with other companies. – P03”

Understanding the relative advantage of BIM has also increased the likelihood of firms to fully utilise BIM in order to provide client satisfaction. For example, P04 mentioned that BIM has been a spotlight to their firms with regards to providing powerful visualisations through integrating BIM with VR and AR, which would enable the client to clearly understand the design and identify any corrections early in the design before proceeding to the construction phase. However, client satisfaction is an added advantage which can be translated into further value such as good business relationships and financial benefit.

> “We are still trying to introduce VR now and we make the 3D using BIM motion then we incorporate VR and AR to our process so that when you give a client, he will be able to go around the building and see his building. It is an added advantage. – P04”

P05 also identified the BIM process as a relative advantage in relation to the ability to collaborate through BIM tools and processes with other professionals that assist architects avoid/mitigate unwarranted amendments on the site. This collaboration between professions would increase the coordination of designs and information and reduce the errors that are like to arise on site. Thereby saving a lot of money and time due to rework that may arise if the designs are not accurately coordinated. For example, P05 from a project experience highlighted tangible benefits of BIM tools such as design coordination and clash detection. This means that relative advantage has a positive reflection on the firm’s performance and ultimate will improve job performance.

> “Revit is an all-around because like in the structural department now, it's tracks issues like where they put a column and it coincides with an architectural function. In so many cases, on site, you might have to call the assistant structural engineer to come to site and make amendments on-site maybe your column is aligning in the middle of a window and in such cases, you might have to move it to a suitable place. – P05”

Despite the assertion that BIM has numerous cost-related challenges, Participant (P06) has demonstrated that the benefits of BIM adoption far outweigh the challenges. For example, P06 disclosed that, in addition to competitive advantage, ROI is the second most important motivator for BIM adoption in their company.

> “Return of investment because really what happened is that those firms time to get more Project and more projects brings more return for them, so they can afford to buy the software and even employ more people or train their staff to use the software because it actually gives them an advantage or an edge over the people that don't use it. they have access to better contracts and people actually pay attention because they can sell themselves better with that so that's it. – P06”

6.2.7.2 Complexity

The degree to which a firm perceives BIM as difficult to utilise or implement has been described as complexity (DOI) and in prior research it has been referred to as perceived ease of use (TAM) or effort expectancy (UTAUT) (see section 3.4.4.2). In the Nigerian SMAFs context, the opinion of the complexity of BIM is contradictory based on the participants' nature of the firm. For example, participants from small-sized firms with BIM level 0 such as P02 believe that BIM tools and processes are more difficult than the conventional way of practice and, therefore, the reason why there has been a slight reluctance in learning the new process.

> Yes, I believe it is honestly harder than AutoCAD it's a bit complex. That is why they are reluctant in learning it. – P02”

On the other hand, participants from medium-sized firms with BIM level 2 such as P11 believed that BIM is not only compatible with their current process but also easy to use and learn. Therefore, it is not complex. However, the size of the firms and the level of BIM maturity might be the reason why their opinions differ. For example, small firms are more agile towards adopting and adjusting to a new work process, but they often have limitations of available resources while the larger firms have more resources at their disposal to develop their BIM capabilities and affect their experience of the adoption and utilisation of BIM.

> “Yes, it is very compatible and no it is not complex it is easy to use and very easy to understand. – P11”

Furthermore, P01 asserted that BIM tools and processes are perceptibly easy to understand by architects due to their experience with similar software as compared to engineers. In contrast to the engineers, the architect are taught how to use digital design tools at the university level, therefore they are familiar with tools such as Revit and as such it is easier to understand and apply the associated BIM processes to their workflow. However, most of the professional business partners such as engineers do not have prior experience with digital design tools beyond AutoCAD and therefore, they perceive BIM tools as complex tools when explained to them by architects. Therefore, this might impact the BIM process within the SMAFs particularly on projects that requires collaboration with external business partners or professionals such as engineers.

> "It depends on the background. For us architects obviously because we are usually quite a bit. But for the engineers they found it a little bit difficult and where a little bit more pessimistic when adopting BIM. However, as soon as we talked them through the process, they realised that it was quite close to the basic software (AutoCAD) that they were used to working with. They realised that maybe there was a common point between working on 2D and working on 3D. So basically, the complexity would depend on what background you have with using similar software. – P01"

Similarly, although there are a variety of BIM compliant tools, the complexity of each BIM tool against another is a determinant factor as to which BIM authoring tool a firm would adopt. Although participants highlighted several BIM compliant tools such as Revit, ArchiCAD and Navisworks, it was also highlighted that personal preference for the BIM tools is influenced by the perceived ease of use. Individuals have different preferences when it comes to BIM authoring tools, according to P04, whereby they personally prefer Revit due to existing experience, skills, competency, and ease of use.

> "Revit is very easy to use. personally, I don't know. you cannot compare it to AutoCAD and other sectors or SketchUp. to me it is not complex but to certain people they prefer SketchUp, and others prefer AutoCAD and others prefer ArchiCAD. Personally, maybe because I have skills in Revit it is very easy to use. – P04"

6.2.7.3 Compatibility

Compatibility is described as the degree to which BIM is perceived as consistent with the existing values, past experiences, and needs of potential BIM adopters. Compatibility of BIM to current workflow makes it easier for employees to accept BIM. For example, P05 highlighted that BIM tools such as Revit is compatible with their workflow process and can be utilised for multiple purposes (i.e., easier to develop 3D design and manage complex information within a single model) unlike the previous tools such as AutoCAD. Therefore, the compatibility of BIM to the workflow of a firm is often perceived as a motivation to utilise BIM particularly when BIM tools and processes are perceived to be more beneficial than the prior tools and processes. Thus, this eases the adoption of BIM tools and integration of BIM technologies into the SMAFs design process and workflow.

> “Yes, it is compatible because there are so many things you can do with Revit, but you cannot do it AutoCAD, but you can do almost everything that AutoCAD I can do in a Revit. Revit is like a universal software. – P05”

Therefore, the choice of BIM tools adopted within the SMAFs is often influenced by the compatibility of the BIM authoring tools available with the current practices in the firms. This has been evident from the participant statements. For example, P01 disclosed that the firm utilises Revit and Navisworks because they fit perfectly into their workflow and are selected due to their compatibility with the current process within the firm.

> “I think for us we choose the software we used based on their compatibility with what we do and that is why I Revit and Navisworks are the favoured software for us because they just got into our work. – P01”

Furthermore, participants such as P02, particularly firms with relatively low levels of BIM maturity, identified the issue of compatibility to be the reason behind their reluctance. For example, when participants were asked about the compatibility of BIM to their current practices, P02 pointed out that BIM adoption is low in their firm because of the compatibility issue. Therefore, establishing BIM processes and workflows within the firms would enable the adoption of BIM technology.

> “yes, it is the issue compatibility. – P02”

Additionally, P08 mentioned when working on a project with a firm that has adopted BIM, the files received were converted to a 2D format and when a 3D design or a BIM model is requested by a client, the firm outsources projects to meet the client’s demand. However, workflow of the firms that adopted BIM is more advantageous than firms that did not adopt BIM in cases where 3D designs are needed. For example, a BIM model contains several file formats and design information such as 3D designs which can be extracted and shared with clients. However, when 3D designs are requested from firms that are yet to adopt BIM, the firms would have to outsourcing the 3D design project otherwise the firm lose the contract and the client.

> “Yes, they're in 2D because those people that you find using Revit are those that are doing 3D for you. once you give them in AutoCAD, I think they converted it to Revit and produce the 3D. – P08”.

Having presented the analysis of the superordinate and their associated subordinate themes namely, individual competence, organisational capability, environmental control, and technological quality as emerged from the interview process within the SMAFs, the discussion of the analysis are presented in the subsequent sections.

6.3 Discussion

The previous section presented qualitative analysis and findings that emerged from the interview verbatim transcripts. Therefore, in the subsequent sections, the discussion of the analysis and findings is presented.

6.3.1 Individual Competency

The development of individual competence (IC) by the SMAFs can be defined as a process that improves the quality of the firm's human resources, including motivation and innovation in small business practices (Lu & Sexton, 2009). These human resources include the individuals within the SMAF such as the employees, digital managers and top manager who are tasked with the professional and productive activities within the firms. Therefore, discussions on the employee, digital manager and top manager are presented in the subsequent sections.

6.3.1.1 Employee

The employee competence is an integral part of the implementation of BIM, and this is especially true for SMAFs, which rely heavily on human resource development to drive innovation (Høyrup, 2010; Tsai & Yen, 2020). Therefore, it is important to consider the quality and competence of employees right from the recruitment phase. The characteristics and traits needed are loyalty, willingness to learn and self-motivation. Competent employees are easily trained and have less resistant to change. Other factors highlighted include age (younger is likely to have advantage over the older), qualification, and prior experience on BIM. McGuirk et al., (2015), presented evidence that the willingness of employees to accept change significantly affects the success of innovation in firms. In the context of Nigerian SMAFs, employee's *"lack of resistance and willingness to learn contributed to the firm's relatively higher level of BIM usage when compared to others - P11*". However, although it is evident that relatively higher BIM maturity level firms consider the experience rather that the educational qualifications, evidence of employees with traits such as willingness to change and learn are equally considered even without prior experience.

6.3.1.2 Digital Manager

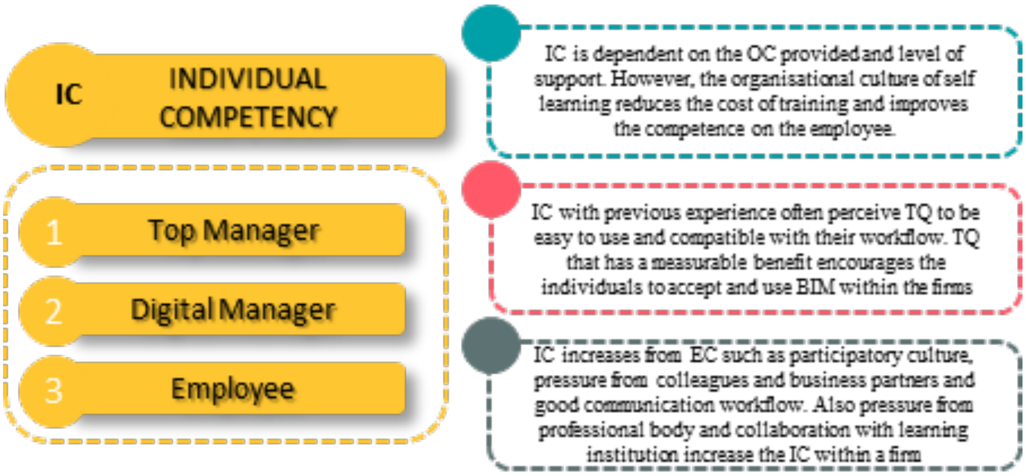
The digital manager plays a decisive role as change facilitator in the process of BIM adoption (Holzer, 2015). In this context, this could be the BIM manager for BIM adopters and an IT manager responsible for championing and leading IT activities for non-adopters. Therefore, it is important for the digital manager to possess the technical know-how of BIM tools, experience, and ability to train others. In the context of Nigerian SMAFs, there is little evidence of the digital manager with BIM knowledge within the firms with relatively low-level of BIM maturity. However, the firms with relatively higher BIM maturity levels highlighted that the IT/BIM manager is responsible for managing and guiding the employees with regards to IT/BIM related issues. Furthermore, the digital manager's nature of employment was highlighted to be crucial to positively influence the full adoption of BIM. Therefore, firms prefer to have digital managers on full time employment basis because it is more cost effective for the firms in the long run.

6.3.1.3 Top Manager

The innovativeness of top managers in firms depends on their willingness and ability to change and to encourage new ways of doing things as discussed in previous section (see section 3.4.3.1). In the Nigerian context, the ability of the top manager influenced to innovate and lack of resistance to change influence BIM adoption. Additionally, the top manager's ability to lead and mentor employees and team is valuable in creating knowledge and organisational culture for learning. Furthermore, the recognition of teamwork attributes and the capacity to inspire others based on Lu and Sexton's (2009) assertion. This indicated that top managers' ability to efficiently connect and communicate would motivate colleagues and employees to innovate, and therefore enable employees to be successful in achieving the desired objective such as the adoption of BIM within the firms.

6.3.2 Individual Competence Summary

A top manager's competency and attitude have a direct impact on employees' performance. Therefore, a top manager that is driven and motivated coupled with a high level of knowledge can lead, mentor and motivate the team underneath. Furthermore, the discussion about the digital manager can be summarised into four main points. Some of the firms which have a low level of BIM highlighted that there is no current digital manager within the firm, while others that claimed that there is no digital manager within the firm upon further discussion disclosed that there is an IT unit. The firms that disclosed the availability of IT units are medium firms. Another category of responses acknowledged that they have an IT manager on a contract agreement and are currently preparing to offer fulltime employment to the IT manager. The last category has a BIM manager in a fulltime role and further discloses the credentials for the position. Additionally, the ability to be trained, willingness to change, skills additional to the qualification, formal or informal skill acquisition are factors identified in relation to the employees in firms. The firms with relatively high levels of BIM activity reported that the factors are considered earlier, such as when recruiting. However, regular training is essential in getting the best performance from employees. Considering the above, Figure 6.4 summarises the key findings of how the individual competence are linked (affects) the other factors.



IC is dependent on the OC provided and level of support. However, the organisational culture of self learning reduces the cost of training and improves the competence on the employee.

IC with previous experience often perceive TQ to be easy to use and compatible with their workflow. TQ that has a measurable benefit encourages the individuals to accept and use BIM within the firms

IC increases from EC such as participatory culture, pressure from colleagues and business partners and good communication workflow. Also pressure from professional body and collaboration with learning institution increase the IC within a firm

Figure 6.4: IC relationship with other factors

6.3.3 Organisational Capability

Organisational capability refers to the firm's capacity to deploy resources such as management support, IT infrastructure, process and policy, and funding to enable BIM adoption (see section 3.4.1). Furthermore, developing organisational capability is crucial to implementing BIM and achieving meaningful result and efficient outcomes during the BIM adoption process (Ahuja et al., 2017). Therefore, the discussion of the management support, IT infrastructure, process and policy, and funding is presented in the subsequent sections.

6.3.3.1 Management Support

Management support is a critical variable that defines successful innovation in SMAFs (see section 3.4.1.1). Therefore, a flexible management system and informal organisation hierarchy structure is conducive to the fostering of knowledge creation is better than rigid bureaucracy. In this regard, Nigerian SMAFs have internalised the importance of knowledge creation as a tool for competitive edge through training and incentives for innovativeness. Subsequently, training identified within the firms are either formal or informal, which could be delivered in-house, and these increase the employee's competence within the firm. Furthermore, firms invest in training few individuals such as IT managers, top managers, and employees with the expectations that the individuals transfer the BIM knowledge to their peers to save overall training cost. Additionally, other channels for BIM training identified within the SMAFs are seminars, workshop or conferences usually organised by the firms, learning institutions or professional bodies. Nonetheless, the management support is influenced by the funding support available at the firm (see section 6.2.5.4).

Informal training through online resources and colleagues within the Nigerian SMAFs usually compliments the formal training provided for the employees (see section 6.2.4.1). However, this depends on the employee's willingness to learn, innovativeness and financial incentivisation from the firm. Similarly, the incentivisation schemes provided by the firm to encourage the employees to learn, innovate and adopt BIM is impacted by the availability of investment funds. However, firms within the Nigerian SMAFs often a consider the level of funding support or financial benefits realise from adopting BIM when developing incentive schemes for the employees though it reflects upon the performance of the employees (see section 6.2.4.1).

6.3.3.2 IT Infrastructure

IT Infrastructure refers to combined facilities such as software, hardware, and network facilities that are used to deploy BIM technologies (See section 3.4.1.2). However, the relationship between the organisational capability and support of SMAFs infrastructure to their success in innovation within the construction industry is explicitly highlighted (see section 3.4.1.2), and particularly linked with the BIM adoption process in the Nigerian context (see section 6.2.5.2).

There is a strong link between the infrastructure required to support the BIM process and the training support provided by the management. It is not sufficient for the management to train the employees without the required infrastructure and vice versa.

Furthermore, literature suggested that the availability of specific technological tools that foster the capture and storing of knowledge, as well as the connection between individuals, are relevant aspects of this component when considering the innovation capacity of firms (section 3.4.1.2). However, there is a notable discrepancy in the level of infrastructure provided by the organisations (section 6.3.3.2). Additionally, infrastructure facility is suggested to have an important role when shaping and supporting the quality of knowledge within the workplace (see section 3.4.1.2), however, evidence shows that Nigerian SMAFs share similar opinion, although the provision of infrastructure has been hindered by the lack of investment funds (see section 6.3.3.2).

6.3.3.3 Policy and Process

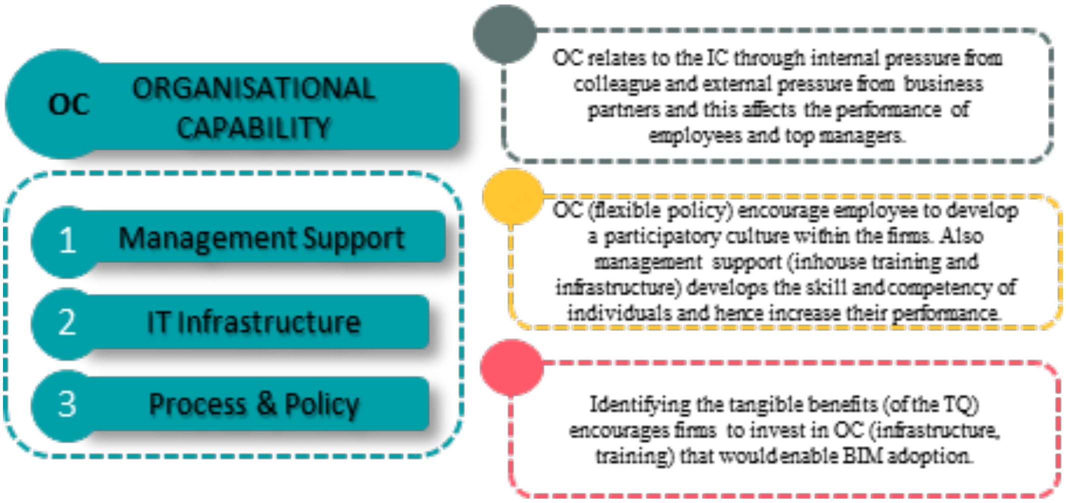
Flexible policy systems that are supportive of innovation and have clear guidelines are explicitly highlighted to have positive impact in enabling a smooth BIM adoption process (see section 3.4.1.3). Friedman et al (2001) suggested that the implementation of a system that accommodates experimentation culture can lead to an improvement in a firm's cultural values for innovation, such as increased trust and transparency, open mentality, mistakes considered as learning opportunities, support for experimentation and the exploration of new territories, and cooperation and mutual help. However, within the Nigerian SMAFs, indication shows that policies are used to encourage the employees to be innovative. This enables the employees to experiment on BIM technology and process within the firms. Furthermore, firms that implement BIM utilise policies such as financial incentivisation and regular training for the employees to encourage and support the continuation of BIM usage within the firms.

6.3.3.4 Funding

Funding is essential to a successful BIM adoption. Although firms have a keen interest in adopting BIM, most firms are reluctant due to factors such as funding. Funding is needed for the organisation to invest in factors that have been associated with influencing BIM adoption, such as training of staff (organising events like workshops), purchase of basic infrastructure (software license, network, hardware, cloud storage). Similarly, for the management to fully support employees there is a need for funding. It has been evident that the firms that invested in purchasing the infrastructure to support BIM have realised benefits in the form of return of investments, change in the mindset and culture of employees, and driving their firm's maturity and capabilities (see section 6.2.5.4: P04 – 5-million-naira charge).

6.3.4 Organisational Capability Summary

Firms with relatively higher BIM maturity level have invested in BIM adoption and charged more from their clients, while firms with relatively low level of BIM are reluctant to invest in BIM because of their perception on potential jobs scarcity. This suggests that there is the need to evaluate the tangible BIM benefits and consider the firms' position in terms of job availability before making decisions to invest in BIM infrastructure. Succinctly, the lack of BIM trained personnel which is associated with the training received in the higher institutions, and the lack of involvement of professional societies coupled with low awareness contributed to the lack of BIM adoption. No legislative provision for BIM adoption leads to no regulation of its usage. Moreover, there is no trace of BIM demand by clients (public or private). In summary, Figure 6.5 presents a summary of the main relationship of the organisational capability with the other categories.



OC relates to the IC through internal pressure from colleague and external pressure from business partners and this affects the performance of employees and top managers.

OC (flexible policy) encourage employee to develop a participatory culture within the firms. Also management support (inhouse training and infrastructure) develops the skill and competency of individuals and hence increase their performance.

Identifying the tangible benefits (of the TQ) encourages firms to invest in OC (infrastructure, training) that wouldenable BIM adoption.

Figure 6.5: OC relationship with other factors

6.3.5 Environmental Control

Environmental control is the impact of internal pressure such as colleagues, peers and superiors and external factors such as professional business partners, government, clients, learning institutions, and regulatory bodies on BIM adoption within the Nigerian SMAFs. In this section, the discussion of the environmental control is presented.

6.3.5.1 Internal Pressure

From the analysis, it is evident that there is internal pressure because of the interaction between the team members, employees, and managers. Although the internal pressure and interaction is required to effectively adopt BIM (Arayici et al., 2011a), this also resulted in fostering the participatory culture within the firm and therefore it is responsible in shaping and developing the organisational culture particularly when it comes to knowledge creation and learning. Furthermore, within the Nigerian SMAFs, team members want to be part of the team and does not want to feel left out. As a result, the team members strive to learn the process and tools that are commonly utilised during the project. This is partly to maintain your image and reputation so that the other members do not think you are inferior or slowing them down. Literature (see section 3.4.2.1) shows that effective communication led to firm's success in BIM adoption (Holzer, 2015). Similarly, in the context of the Nigerian SMAFs, there is a fluid workflow and open transparent communication channels between different hierarchy such as employees and top managers. This effective communication allows knowledge transfer between the employees and increases the overall performance and skills of the employee with regards to BIM adoption.

6.3.5.2 External Pressure

The interaction of SMAFs with business partners is essential in exerting the external pressure needed for BIM adoption (see section 6.2.6.2.1). This means that the interaction with a business partner that has a relatively higher and extensive knowledge of BIM can encourage firms to adopt BIM within the SMAFs to maintain good relationship and win more projects. Hence, a potential lens to explore and increase BIM adoption within SMAFs is through the leadership and encouragement of the firms with higher BIM compliance. Similarly, the benefits of using BIM tools (i.e., provide clear 3D visualisation that win over clients) to develop presentations and concept designs to present to the clients makes BIM desirable by the firms. Therefore, clients are charged extra for the value and experience provided to them through BIM. Additionally, professional business partners such as engineers also influence the ways the SMAFs utilise BIM tools during a project delivery. Although the architect uses BIM to a certain extent within their environment, there is still a limitation to BIM usage when sharing information with professional partners such as engineers that have little experience with BIM tools. This means that the architects need to alter their design process through converting their designs to maintain relationship with other professionals such as engineers and this leads to the use of lonely BIM within their environment.

Furthermore, the competitiveness of the marketplace provides an opportunity for BIM users to benefit (see section 6.2.6.2.2). Therefore, the value of BIM in the marketplace has a significant influence on BIM adoption. The higher the demand for BIM, the more the financial benefit, which has served to encourage Nigerian SMAFs to adopt BIM.

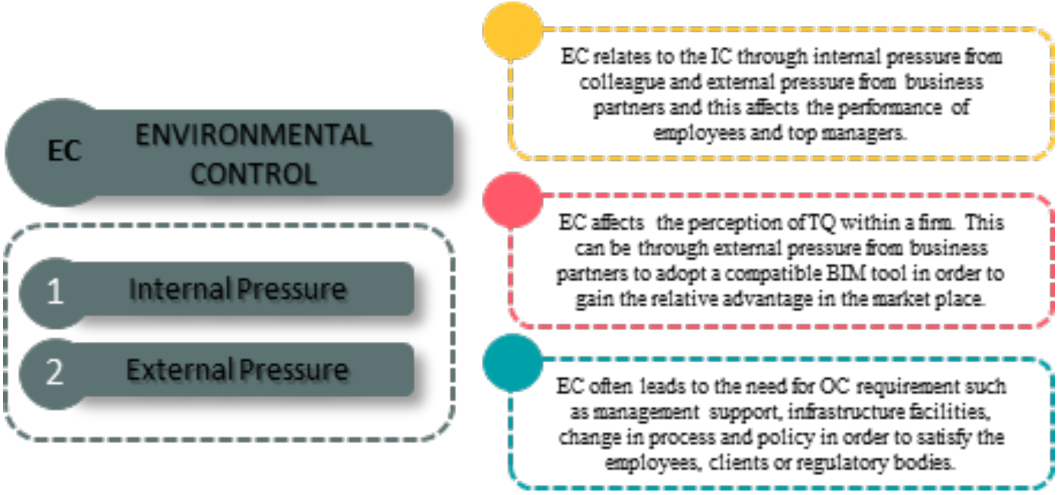
Professional and regulatory bodies are reported to have an influence on enforcing a BIM adoption mandate within SMAFs and the industry at large, particularly in developed countries (Gurevich and Sacks, 2020). In Nigeria, although there is no mandate, all the participants, to a certain extent, believe that the professional and regulatory bodies have a role to play for BIM to be adopted by Nigerian SMAFs. Contrary to this, in South Korea, indication shows that regulatory pressure may negatively affect BIM acceptance (Lee et al, 2017). However, in the Nigerian context, the participants have unanimously agreed that the professional and regulatory body needs improvement to be able to accommodate or push BIM adoption within the SMAFs. Although, the professional bodies have been making an effort towards raising awareness through seminars, workshop and training, there is still the need for professional and regulatory body to assume a leadership role in (i) developing curriculum of learning institutions to accommodate BIM and, (ii) encouraging the government to provide guidelines for the BIM mandate. Furthermore, developing updated standard for building approval to accommodate BIM would improve the overall adoption within Nigerian SMAFs (see section 6.2.6.2.3).

Educational and learning institutions have been identified to play a crucial role in providing the industry with BIM resources and professionals that are proficient in BIM. Therefore, there is a need to improve the curriculum, and, above all, there is also the need to discuss how BIM education can impact organisational structures and talent acquisition strategies within Nigerian SMAFs. This will not only mitigate the identified challenges (see section 6.2.2.3) of employee shortage or lack of BIM awareness but also the lack of trained personnel and knowledgeable graduates.

The role of the government in driving BIM adoption through policies, mandate or funding has been apparent, particularly in developed countries (see section 2.5.3). In Nigeria, the government is the major client and perceived to play a role towards the success of BIM adoption within Nigerian SMAFs through encouraging or supporting the SMAFs or through developing BIM related policies and mandates. However, due to the government's lack of BIM awareness, there has been little or no interest with regards to BIM adoption. Additionally, corruption within the Nigerian industry due to lack of professionalism has been highlighted to negatively affect BIM adoption within the SMAFs. Although Kori and Kiviniemi, (2015) argued that BIM has been recognised to reduce corruption in the building sector which has been a challenge to the economic development of a nation, the Nigerian government are still not leveraging BIM to curb the corruption.

6.3.6 Environmental Control Summary

Incentivisation as identified has influence on several other factors that also influence BIM adoption within Nigerian SMAFs either directly or indirectly. The direct influence can be seen in the performance of employees. For example, firms that offer incentives as motivation to their employees are reported to have developed a unique culture within the firm that supports learning and competition between the employees. This culture has shaped the communication channel to be open between team managers and team members. Incentive is also a reflection of the organization's financial capabilities, which has been discussed in the funding section. For example, firms that financially benefit from completing a project are likely the firms to offer incentives. Furthermore, Figure 6.6 presents a summary of the key findings with regards to the environmental control and its relationship with other factors.



EC relates to the IC through internal pressure from colleague and external pressure from business partners and this affects the performance of employees and top managers.

EC affects the perception of TQ within a firm. This can be through external pressure from business partners to adopt a compatible BIM tool in order to gain the relative advantage in the market place.

EC often leads to the need for OC requirement such as management support, infrastructure facilities, change in process and policy in order to satisfy the employees, clients or regulatory bodies.

Figure 6.6: EC relationship with other factors

6.3.7 Technological Quality

Technology quality is the degree to which the potential adopter's perceive BIM's relative advantage, compatibility, and complexity as an essential factor for BIM adoption within the SMAFs. In this section, the discussion of the technology quality is presented.

6.3.7.1 Relative Advantage

Relative advantage is the degree to which BIM is perceived as being better that the idea it supersedes which is often expressed in economic profitability (Addy et al., 2018). Similarly, Nigerian SMAFs have identified the increase of firm's overall performance and value through efficient project delivery to be among the benefits of BIM (see section 6.2.2.2). Additionally, firms that realise higher return of investment due to BIM adoption claimed that the documented evidence of tangible BIM advantages encouraged their decision to adopt BIM. Therefore, firms that absorb the initial capital investment cost claimed to have gained back the capital investment within a short period among other benefits (see section 6.2.2.2). Similarly, when Nigerian SMAFs adopt BIM, the firms have an advantage of charging more fees due to the increase in the value provided and winning more contracts. Therefore, the more financial inflow, the more chances of providing management support such as training of personnel, incentives for the employees and upgrading the firm's infrastructure.

6.3.7.2 Complexity

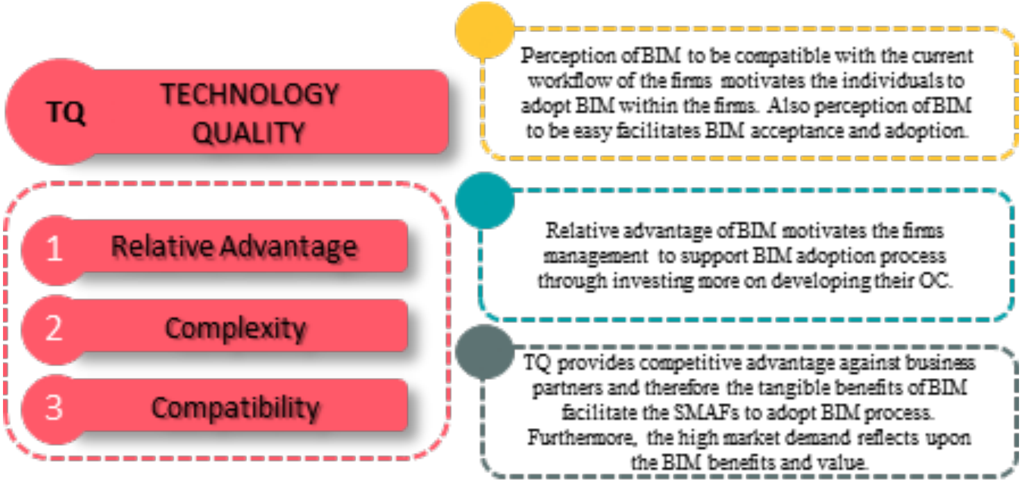
Previous literature has identified complexity of BIM to be a negative influencing factor to BIM adoption (S. Babatunde, Udeaja, et al., 2020; Tan et al., 2019). Similarly, in the context of Nigerian SMAFs, complexity is a crucial factor that is critical to BIM adoption. However, from the analysis, the perception of the complexity of BIM technology is impacted by the individual's experience of similar BIM tools. Furthermore, the perception of BIM complexity can also be influenced by individual competence factors such as individuals' background and environmental control factors such as other professional partners. Additionally, employees with prior experience of digital design tools such as Revit have some level of familiarisation and understanding of BIM tools compared to other professionals such as engineers. Therefore, their perception on the complexity of BIM tools and process is not the same as employees with prior experience which might perceive BIM as a complex concept to implement. Thus, the perception of BIM complexity might affect the attitude of the employees when adoption BIM.

6.3.7.3 Compatibility

Compatibility is described as the degree to which BIM is viewed as compatible with the current beliefs, past perceptions, and needs of future adopters (see section 3.4.4.1). Son, Lee, & Kim, (2015) stated that BIM adoption tends to improve when BIM is consistent with the firm's current work processes. However, SMAFs can struggle not only with using BIM tools and processes, but with also incorporating BIM into their existing business processes and organisational culture. Therefore, there is need to understand how BIM is compatible with the current workflow of the Nigerian SMAFs in order to improve their adoption of BIM. Additionally, the individual experience of similar BIM tools influences the individual judgement of BIM compatibility with current tools and process which also facilitates BIM incorporation within existing business processes and organisational culture.

6.3.8 Technology Quality Summary

The technology quality component consisting of relative advantage, compatibility and complexity of the technology is an important factor that influences BIM adoption within Nigerian SMAFs. The relative advantage is often associated with the complexity and compatibility of the BIM tool with the previously utilised tools within the firms. However, understanding the advantages of BIM tools increases the likelihood of adopting BIM. Similarly, the easier the BIM tools integrate into the process of project delivery, the more acceptable the BIM tools become by employees. Therefore, firms with lower BIM maturity level associated their low BIM adoption rate with the employees perceived complexity of BIM. It is important for SMAFs to evaluate BIM benefits in terms of the relative advantage within their firms as it is equally important for the firms to assess the compatibility of BIM to their project delivery process. Subsequently, complementing the assessment with support from the management with regards to training of the employees can influence their perception of the complexity of BIM and hence, increase the chances of the employees to accept and practice BIM. The summary of the key findings of the relationship of technology quality and other factors are presented in Figure 6.7.



Perception of BIM to be compatible with the current workflow of the firms motivates the individuals to adopt BIM within the firms. Also perception of BIM to be easy facilitates BIM acceptance and adoption.

Relative advantage of BIM motivates the firms management to support BIM adoption process through investing more on developing their OC.

TQ provides competitive advantage against business partners and therefore the tangible benefits of BIM facilitate the SMAFs to adopt BIM process. Furthermore, the high market demand reflects upon the BIM benefits and value.

Figure 6.7: TQ relationship with other factors

6.4 Chapter Summary

This chapter analysed and discussed the findings of the fieldwork which involved interviews carried out with 17 different participants in the architectural firms. The findings highlighted the main factors for BIM adoption, the motivation and the process of BIM adoption within the Nigerian SMAFs. The study suggested that the main motivational factor that influence BIM adoption is the potential and tangible benefit of BIM to the firms. Similarly, the relationship between factors such as individual competence, organisational capability, environmental control and technological quality was established. Furthermore, the factors were explored through the lens of previous literature and the Nigerian SMAFs. The next chapter discusses the process of the framework development and validation through the culmination of the findings from the literature review, quantitative survey, and qualitative interview.

7 Chapter Seven – Framework Development & Validation

7.1 Chapter Overview

In the previous chapter, findings from the qualitative interview process were analysed and discussed. Furthermore, the discussion chapter presented the BIM adoption processes within Nigerian SMAFs and subsequently established the relationships between the superordinate (i.e. individual competence, organisational capability, environmental control, and technological quality) and associated subordinate themes based on the verbatim transcripts of the interview. The essence of establishing the relationship between the key factors that influence BIM adoption (as described in the previous chapter) is to develop a framework to explain this process within Nigeria SMAFs. Therefore, this chapter uses data from all the previous analyses to develop the framework and applies the Analytic Hierarchy Process methodology to prioritise the factors. The framework presents firms with a practical understanding of the BIM adoption process to enable them to focus and prioritise their resources towards BIM adoption. Thus, this chapter presents the discussion of the process of the framework, which was developed through the synthesis of the findings from the literature review, the quantitative survey, and the qualitative interviews. Furthermore, the validation of the framework through a small-scale interview is also presented. The outcome of the validation interview outlines the practical implications of the study as presented at the end of the chapter.

7.2 Framework Development Process

The purpose of this section is to develop the BIM adoption framework (BIMAF) for Nigerian SMAFs, which would help them to understand the process of BIM adoption, evaluate the key factors that influence this process, and thereby manage their resources. As shown in Figure 7.1, the BIMAF development process involves the following stages.

1. Structuring of the framework to fit the aim of the study, which is to develop a BIMAF for Nigerian SMAFs.
2. Establishing the weighing of the key factors that influence BIM adoption to prioritise the categories and components included in the BIMAF.
3. Developing the proposed BIMAF for Nigerian SMAFs that best describes the adoption process in relation to the key influential factors.
4. Creating an interactive digital prototype for the proposed BIMAF to enable Nigerian SMAFs to easily understand and utilise it for their practice.

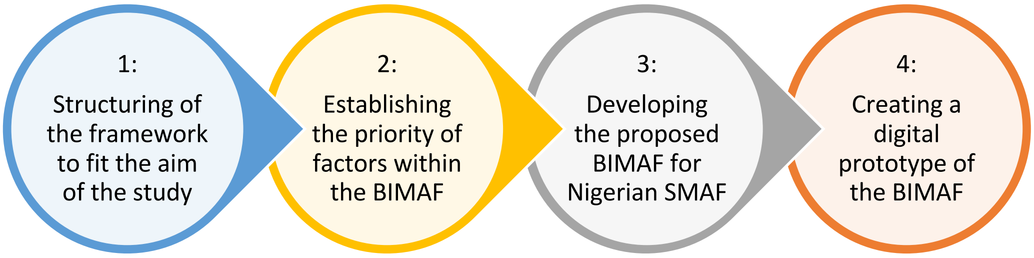


Figure 7.1: Development process of the BIMAF for Nigerian SMAFs

7.3 Stage 1: Establishing the Framework Structure

The outcomes of the empirical phase of the research design were considered to establish the structure of the framework. The empirical phase consisted of a two-step data enquiry phase comprising the quantitative survey and qualitative interview. From the quantitative survey study, the key factors influencing BIM adoption process were solidified based on empirical evidence. Furthermore, empirical evidence of the relationship between the key factors, which were clustered into four categories and their associated components, was established. These findings from the quantitative study formed the first part of the framework where the BIM adoption categories (BIMAC) were presented. Additionally, the second empirical enquiry stage, which was the qualitative interview study, not only provided an in-depth understanding of the relationships between the key factors (i.e. categories and components) that influence BIM adoption within Nigerian SMAFs, but also provided an in-depth analysis and discussion of the BIM adoption process and how each of the factors influences the adoption process. Furthermore, from the findings of the qualitative study, the BIM adoption process can be understood through the five BIM adoption stages, namely: knowledge acquisition (*KA*), persuasion strategy (*PS*), decision making (*DM*), implementation process (*IP*), and confirmation of continuation stage (*CC*). Therefore, the second part of the framework is based on the BIM adoption process (BIMAP), which was elicited from the outcome of the qualitative study.

Considering the above, Figure 7.2 shows the initial sketch of the BIMAF structure based on the idea generated from the discussion above. The initial structure itemises the key sections of the BIMAF, which consist of the BIMAC and the BIMAP, as discussed above. However, to understand the initial sketch, a detailed figure was designed (see Figure 7.3).

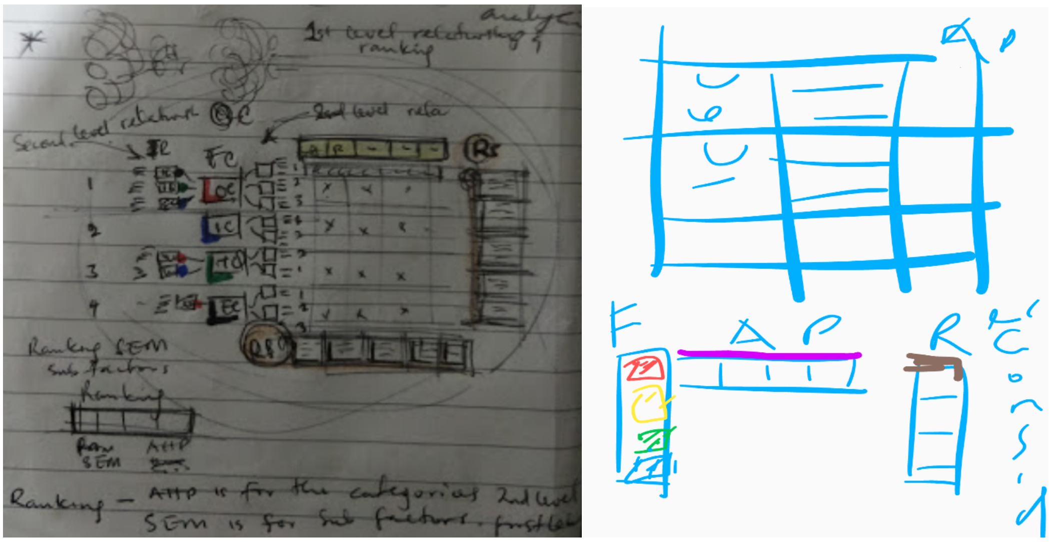


Figure 7.2: Initial sketch of the BIMAF structure

Figure 7.3 shows the six-step sequential process to establish the *BIMAF* structure, which consists of three steps for the *BIMAC* and another three steps for the *BIMAP*. The first three steps are associated with the first part of the framework (i.e. the BIMAC), while the last three steps are associated with the second part of the framework (i.e. the BIMAP). In this regard, Step 1 highlighted the key categories of the *BIMAC,* which are the *OC*, *IC*, *EC*, and *TQ*. These categories are colour coded for easy identification and organised by their level of importance, which was determined through the AHP ranking method. Therefore, the top category (i.e. *OC*) represents the most important, and the bottom category represents the least important. Step 2 highlighted the associated components of each category. For example, the *OC* has three components, i.e. management support, IT infrastructure, and process and policies. These components are also ranked on their level of importance through a pairwise comparison process. Step 3 presents the relationship between the components within the categories as established in the quantitative interview study (for example, the relationship between the *OC* and the *IC*, *EC*, and *TQ*). Consequently, in Step 4, the BIM adoption process stages (i.e., *KA, PS, DM, IP, CC*) are presented horizontally to allow each BIM adoption process to be mapped onto the four categories of the BIMAC. This makes it easier for users to understand the relationship of each adoption stage to the BIMAC categories. The next step (Step 5) provides information on how the components within the four categories influence the BIM adoption process. The last step (Step 6) presents a summary of the adoption process.

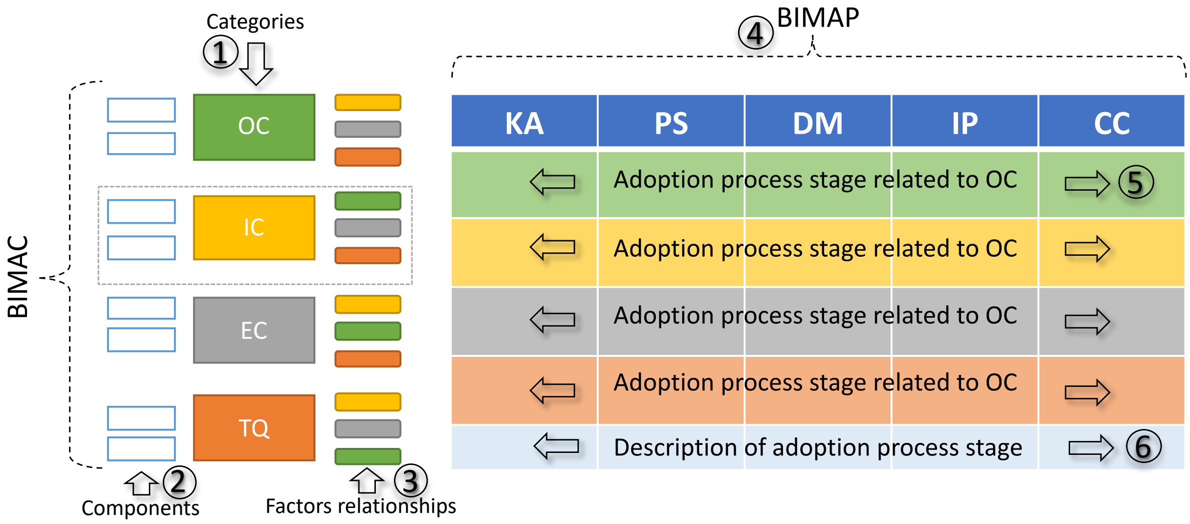


Figure 7.3: Nigerian SMAFs BIMAF Structure

Having established the structure of the framework, the subsequent section presents the process of establishing the priorities within the first part of the framework, which is the BIMAC.

7.4 Stage 2: Establishing the Priorities within BIMAC

While developing the BIMAC, the concept of AHP methodology was utilised to establish the relative weight and priority of the respective elements. Considering this, the BIMAC structure adopted a hierarchy format consisting of four levels. The first level is reserved for the most important factor when establishing the overall goal of the subject matter (i.e. the development of the BIMAC hierarchy). The second level is allocated to the four main categories of the factors that influence the BIM adoption within Nigerian SMAFs (i.e. organisational capability, individual competency, environmental control, and technology quality). The third level consists of the 11 components that were grouped to form the four categories, and the fourth level consists of the criteria that indicate and define the 11 respective components. However, only the first, second (i.e. category level) and third levels (i.e. component level) will be prioritised using the AHP method of analysis because the criteria that indicate the 11 components have been prioritised (in Chapter 6) using structural equation modelling (SEM) to establish the ranks and relationships between the factors. Therefore, Figure 7.4 shows an example of the structure of the BIMAC where “CATEGORY” with the code “C” represents the second level and its respective components “a, b, and c” depict the third level. Furthermore, the numbers “1, 2, and 3” beside the components depicts the priority level (i.e. “1” is the highest priority and “3” is the lowest priority). Similarly, taking an example [component a], the associated criteria “a, b, c,… e” are the indicators of the respective components, which are also listed by their priority level (i.e. where “i” indicates the highest priority and “v” indicates the lowest priority). In this regard, in the subsequent section, the ranking/prioritisation of the category level and component level will be presented.

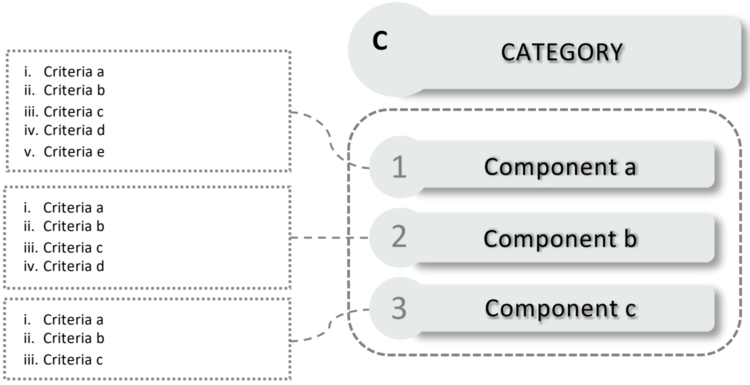


Figure 7.4: Sample of the priority structure of the BIMAC

7.4.1 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a multi-criteria decision (MCD) method used to evaluate the relative importance (priorities) of factors that affect decision making (Saaty, 1987). According to Presley (2006), the AHP model is a decision-making paradigm that implies a hierarchical unidirectional link between decision levels. It quantifies the relative priorities/weights of a given set of criteria based on the evaluation by a group of experts through a scaled comparison that indicates the extent to which one criterion dominates another. The scaling process is then translated into priority weights for the criteria or alternatives. AHP has been widely applied in several fields of research, including construction engineering and management (Ameyaw et al., 2016), thus indicating its usefulness as a multi-criteria decision method. However, prominent amongst the limitations of AHP is the difficulty in applying the paired comparison (Liu & Hai, 2005), particularly where the criteria are many (Hadi-Vencheh & Niazi-Motlagh, 2011). For example, 10 criteria can yield 40 paired comparisons that can be very laborious, if not unfeasible, for decision-makers (Gbadamosi et al., 2019). However, given the small number of attributes identified in this study, the AHP approach was deemed appropriate.

Additionally, the BIMAC categorisation of the attributes constituted a hierarchical structure, which fits well with the structure of AHP. In this regard, Figure 7.5 shows the steps considered when prioritising the BIMAC attributes as adapted from Saaty (1987). Steps one and two have been discussed in the previous section (section 7.4), while the next section will present the pairwise comparison constructs.

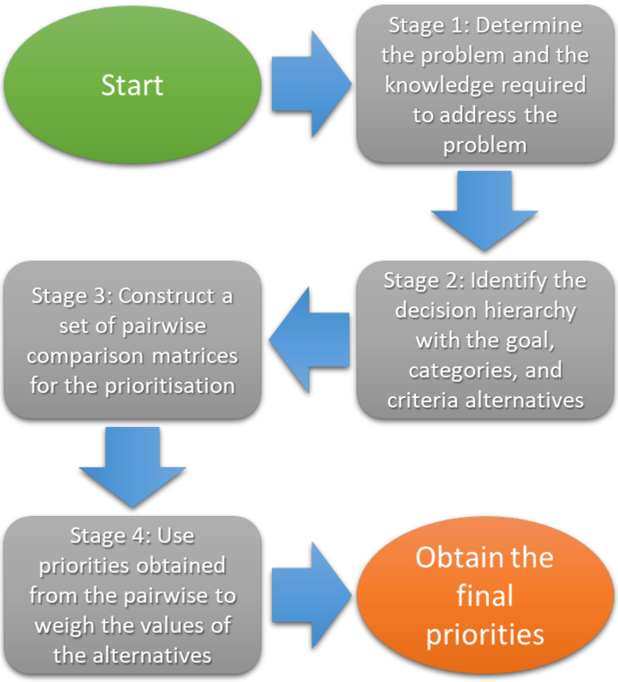


Figure 7.5: The AHP application flowchart diagram

7.4.2 Establishment of the Pairwise Comparison

The pairwise comparison stage is carried out after creating the hierarchy framework (i.e. after organising the phenomenon into a hierarchical dimension) to evaluate the relative importance of each criterion and sub-criterion (Saaty, 1987). Therefore, it is important to break down a complex system into a set of pairs for comparison, because the pairwise comparison evaluates the relative value (i.e. rank, priority, or importance) of elements at the same level of the hierarchy. For example, the category level can have a comparison between *organisational capability* and *individual competence* in the BIM adoption process within Nigerian SMAFs. The comparison would question which of the categories is more important and scale the preference from 1 to 9. This pairwise comparison scenario can be facilitated by Analytical Hierarchy Process Online Software (AHP-OS) (Goepel, 2018). However, to conduct a reliable AHP for this research, respondents were selected through a purposeful method of sampling, which will be explained in the section that follows.

7.4.3 AHP Pairwise Comparison Participants Selection

The purpose of the pairwise comparison is to rank each pair of categories and components through the knowledge and experience of the AHP participants. However, during the qualitative interview process, participants were asked to indicate their interest in participating in future activities of the study, to which all participants

(17) stated their interest. Before conducting the AHP exercise, potential participants were sent an invitation email along with a participant information sheet and consent form. The participant information sheet explains the aim of the study and outlines the ethical considerations, while the consent form serves as a confirmation of the participant's willingness to participate. Saaty (1987) recommended between five and 20 AHP panellists who should be highly skilled with specific expertise and experience in the subject area. In addition, to capture unbiased and diverse knowledge, it is beneficial to introduce a heterogeneous group of participants (Maxwell, 2008). Accordingly, as shown in Table 7.1, 10 participants were selected based on their responses to the consent form. However, besides the participants' years of experience, their positions and understanding of the BIM adoption process within Nigerian SMAFs, as discussed in the previous chapter (see section 6.2.3), prove that they possess sufficient understanding of the subject area to be involved in the AHP exercise. In this regard, the interviews with the targeted participants were conducted through a telephone interview in May 2021.

Table 7.1: List of AHP participants

S/No	Code	Position	Firm Size (FS)	BIM level (BL)	Years of Experience
P01	Alpha	Head of Unit	51 - 250 Staff – Medium	Level 2: Collaboration	11
P02	Bravo	Designer & Supervisor	10 - 50 Staff – Small	Level 0: CAD	
P03	Charlie	Project Manager	10 - 50 Staff – Small	Level 1: Model	
P04	Delta	CEO	< 10 Staff – Micro	Level 2: Collaboration	11
P05	Echo	Site Supervisor	51 - 250 Staff – Medium	Level 1: Model	
P06	Foxtrot	Head of Planning Unit	51 - 250 Staff – Medium	Level 2: Collaboration	25
P07	Golf	CEO	10 - 50 Staff – Small	Level 1: Model	28
P08	Hotel	Designer	< 10 Staff – Micro	Level 1: Model	
P09	India	Designer & Supervisor	10 - 50 Staff – Small	Level 1: Model	22
P10	Juliet	Project Manager	51 - 250 Staff – Medium	Level 1: Model	
P11	Kilo	Owner	< 10 Staff – Micro	Level 2: Collaboration	15

P12	Lima	Site Supervisor	10 - 50 Staff – Small	Level 1: Model	
P13	Mike	Project Manager	51 - 250 Staff – Medium	Level 1: Model	12
P14	November	Project Manager	< 10 Staff – Micro	Level 1: Model	15
P15	Oscar	Site Supervisor	10 - 50 Staff – Small	Level 1: Model	
P16	Papa	Designer & Supervisor	< 10 Staff – Micro	Level 1: Model	18
P17	Quebec	Designer Supervisor	10 - 50 Staff – Small	Level 1: Model	20

7.4.4 The Output of the AHP Pairwise Comparison

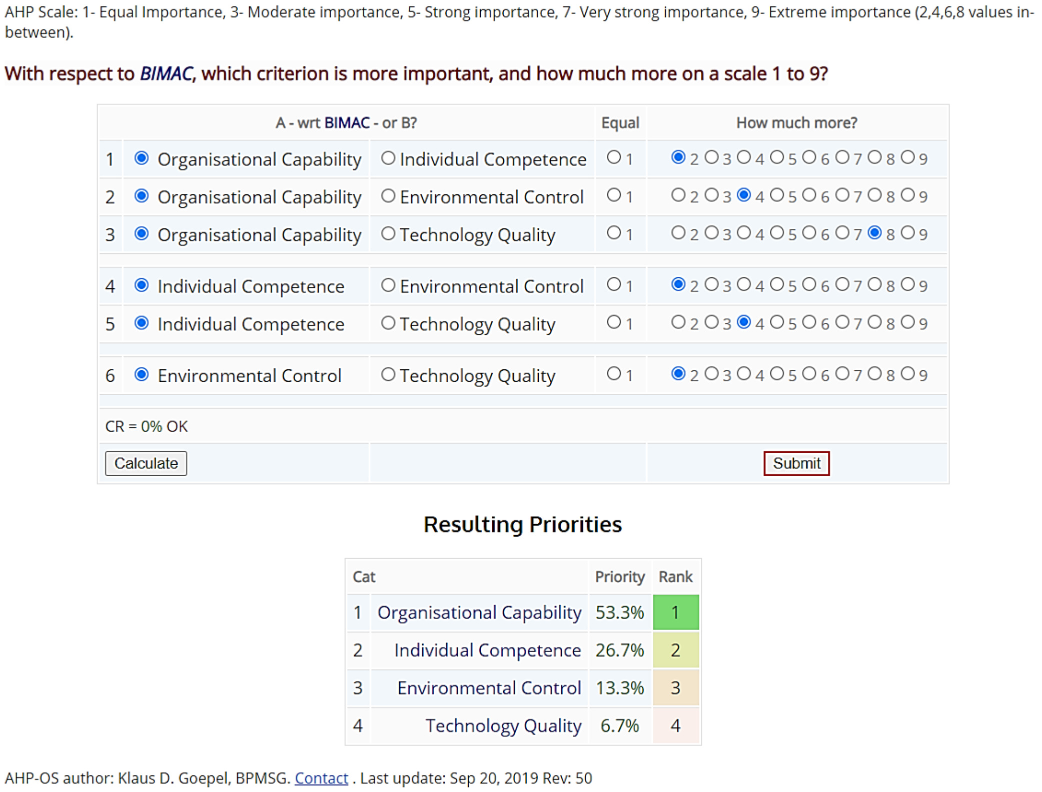
To evaluate and analyse each pair of categories and components, the AHP-OS tool was used as the primary tool. Before assessing the relative weights of each category and component, the AHP exercise results were reviewed for consistency. The AHP-OS calculates the consistency ratio (CR) based on the degree of inconsistency in the data inputted, which assures participants reliability when establishing the category and component priorities (Goepel, 2018). Furthermore, the AHP-OS indicates the acceptability of the pairwise comparison based on the CR; in situations where the CR is unacceptable, the AHP-OS suggests ways to enhance it (i.e. the pairwise comparison process should be reviewed and improved). Goepel (2018) highlighted that disparity or inconsistency within the pairwise comparison is permitted if the CR value is less than or equal to 10%. However, in situations where the CR exceeds 10%, subjective judgments are utilised to evaluate the pairwise comparison; therefore, the lower the consistency ratio, the greater the acceptability. In this regard, Table 7.2 shows the CR results of each pairwise comparison category. The results show that all categories have a CR of 0%, which is acceptable based on Goepel's (2018) criteria.

Table 7.2: AHP consistency ratio measurement

	Pairwise Categories	Matrix Size	Pairwise Comparison(s)	CR
1	BIMAC	4*4	6	0.00%
2	Organisational Capability	3*3	3	0.00%
3	Individual Competence	3*3	3	0.00%
4	Technology Quality	3*3	3	0.00%
5	Environmental Control	2*2	1	0.00%

7.4.5 AHP Pairwise Comparison Synthesis

An evaluation of the relative priority and rank of the categories and components was conducted using AHP-OS based on participants' judgments. The process was iterative to ensure the consistency ratio was within the acceptable range (less than 10%), as shown in Table 7.2. An evaluation of the four categories for BIMAC involved six pairwise comparisons where the participants were asked "with respect to BIMAC, which criterion is more important, and how much more on a scale of 1 to 9?" Figure 7.6 shows a screenshot of the pairwise comparison (6) for the category level of the AHP hierarchy framework and the resulting priorities generated from the exercise.



AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

With respect to *BIMAC*, which criterion is more important, and how much more on a scale 1 to 9?

	A - wrt BIMAC - or B?		Equal	How much more?
1	● Organisational Capability	○ Individual Competence	○ 1	● 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
2	● Organisational Capability	○ Environmental Control	○ 1	○ 2 ○ 3 ● 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
3	● Organisational Capability	○ Technology Quality	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ● 8 ○ 9
4	● Individual Competence	○ Environmental Control	○ 1	● 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
5	● Individual Competence	○ Technology Quality	○ 1	○ 2 ○ 3 ● 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
6	● Environmental Control	○ Technology Quality	○ 1	● 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9

CR = 0% OK

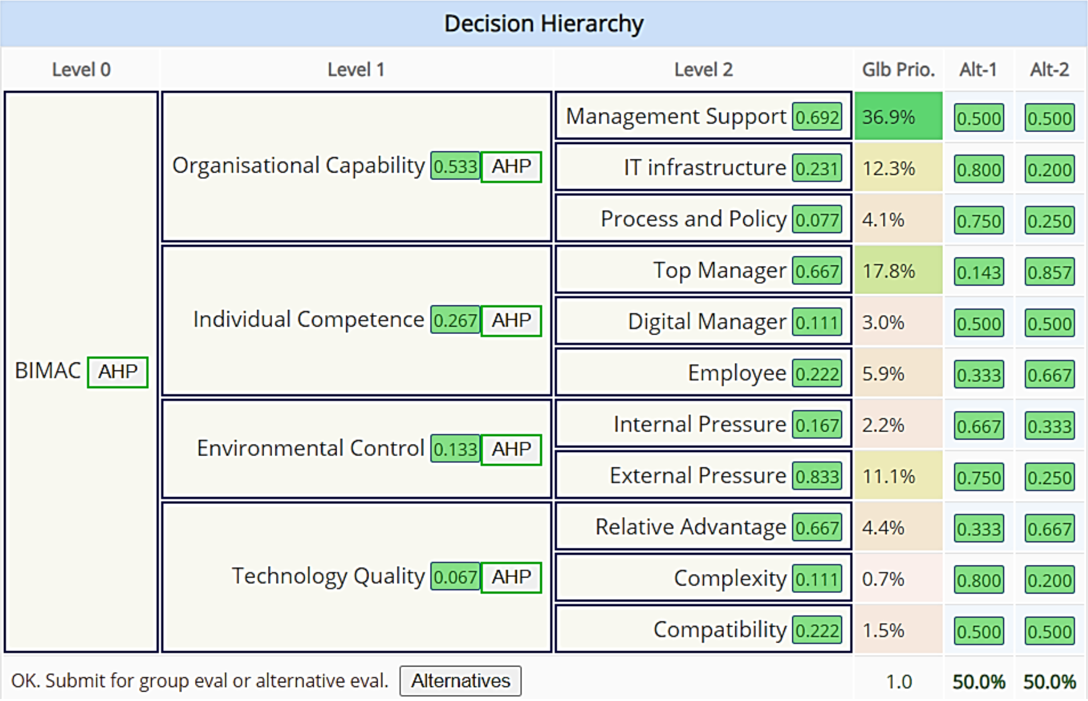
Resulting Priorities

Cat		Priority	Rank
1	Organisational Capability	53.3%	1
2	Individual Competence	26.7%	2
3	Environmental Control	13.3%	3
4	Technology Quality	6.7%	4

AHP-OS author: Klaus D. Goepel, BPMSG. Contact . Last update: Sep 20, 2019 Rev: 50

Figure 7.6: Category level AHP: Pairwise comparison

A similar process was followed to obtain the resulting priorities of the component level of the AHP hierarchy framework. As a result, an overview of the resulting outcome of the AHP exercise is presented in Figure 7.7. The overview shows the decision hierarchy based on the levels and associated categories and components. It also shows the priority percentage of the components based on the pairwise comparison exercise. Additionally, two alternatives were generated, and the result shows an equal percentage. In this regard, the synthesis of each pairwise comparison is discussed in the subsequent sections.



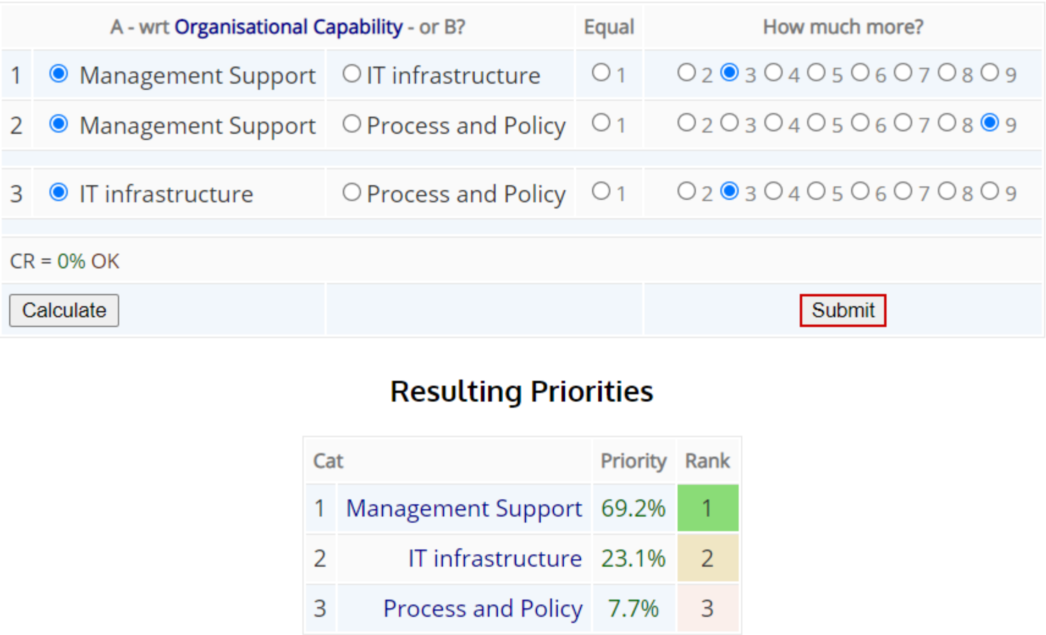
Decision Hierarchy

Level 0	Level 1	Level 2	Glb Prio.	Alt-1	Alt-2
BIMAC AHP	Organisational Capability 0.533 AHP	Management Support 0.692	36.9%	0.500	0.500
		IT infrastructure 0.231	12.3%	0.800	0.200
		Process and Policy 0.077	4.1%	0.750	0.250
	Individual Competence 0.267 AHP	Top Manager 0.667	17.8%	0.143	0.857
		Digital Manager 0.111	3.0%	0.500	0.500
		Employee 0.222	5.9%	0.333	0.667
	Environmental Control 0.133 AHP	Internal Pressure 0.167	2.2%	0.667	0.333
		External Pressure 0.833	11.1%	0.750	0.250
	Technology Quality 0.067 AHP	Relative Advantage 0.667	4.4%	0.333	0.667
		Complexity 0.111	0.7%	0.800	0.200
		Compatibility 0.222	1.5%	0.500	0.500
OK. Submit for group eval or alternative eval. Alternatives			1.0	50.0%	50.0%

Figure 7.7: Overview of the AHP: Pairwise comparison results

8.1.1.1 Cluster One: Organisational Capability

The ranking of the organisational capability came first in the spectrum of categories with a 0.533 (53.3%) degree of importance, as shown in Figure 7.7.



	A - wrt **Organisational Capability** - or B?		Equal	How much more?
1	● Management Support	○ IT infrastructure	○ 1	○ 2 ● 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
2	● Management Support	○ Process and Policy	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ● 9
3	● IT infrastructure	○ Process and Policy	○ 1	○ 2 ● 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9

CR = 0% OK

Resulting Priorities

Cat		Priority	Rank
1	Management Support	69.2%	1
2	IT infrastructure	23.1%	2
3	Process and Policy	7.7%	3

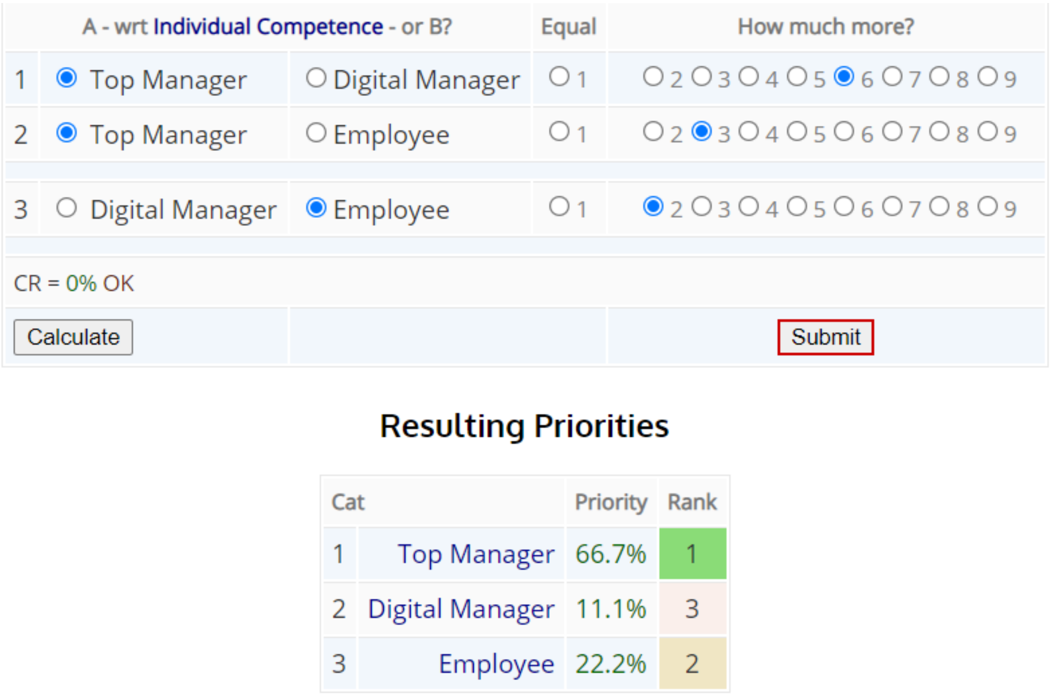
Figure 7.8: OC components: AHP pairwise comparison

Furthermore, from Figure 7.8, the components of the organisational capability category show that management support has the highest level of importance, with a

69.2% degree of importance, followed by the IT infrastructure, which was ranked second with a 23.1% degree of importance. Consequently, process and policy were ranked third in the priority list with a 7.7% degree of importance.

8.1.1.2 Cluster Two: Individual Competency

With a degree of importance of 0.267 (26.7%), individual competence ranked second in the categories of factors that influence BIM adoption within SMAFs, as shown in Figure 7.7. Additionally, Figure 7.9 depicts the result of the pairwise comparison between the components of the individual competence category. The result ranked the top manager as the most important component within the category with an importance degree of 66.7%, while employees were ranked second with a degree of importance of 22.11%. The digital manager's lowest priority is ranked as the third component in the individual competency category, with an 11.11% degree of importance.



	A - wrt **Individual Competence** - or B?		Equal	How much more?
1	● Top Manager	○ Digital Manager	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ● 6 ○ 7 ○ 8 ○ 9
2	● Top Manager	○ Employee	○ 1	○ 2 ● 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
3	○ Digital Manager	● Employee	○ 1	● 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9

CR = 0% OK

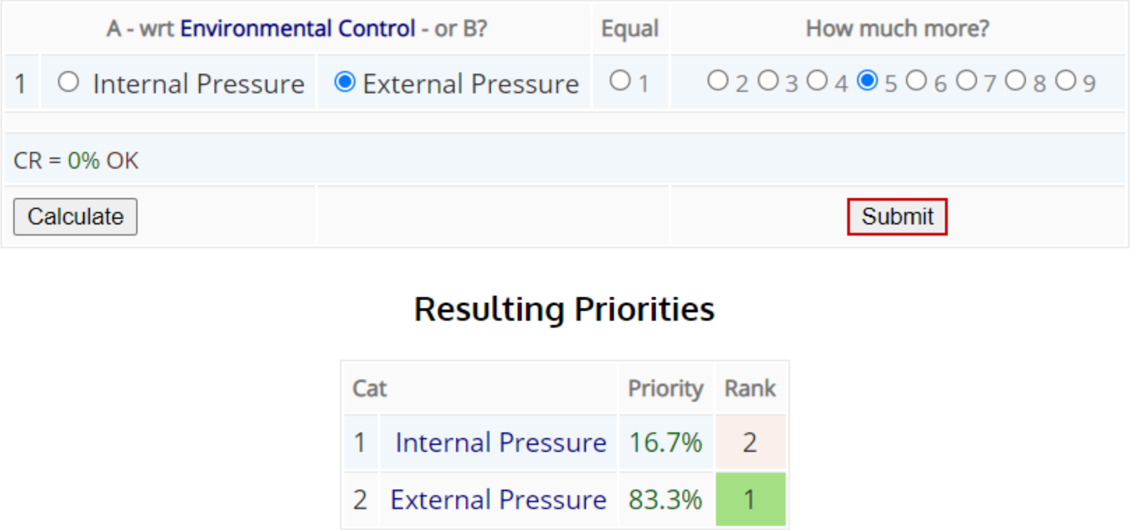
Resulting Priorities

Cat		Priority	Rank
1	Top Manager	66.7%	1
2	Digital Manager	11.1%	3
3	Employee	22.2%	2

Figure 7.9: IC components: AHP pairwise comparison

8.1.1.3 Cluster Three: Environmental Control

Environmental control, with a degree of importance of 0.133 (13.3%), is prioritised as the third most important category level of the AHP hierarchy, as shown in Figure 7.7. Furthermore, Figure 7.10 highlighted the result of the pairwise comparison between the components of environmental control (i.e. internal pressure, and external pressure yielding) whereby external pressure is more important than internal pressure at 83.3% degree of importance.



	A - wrt **Environmental Control** - or B?		Equal	How much more?
1	○ Internal Pressure	● External Pressure	○ 1	○ 2 ○ 3 ○ 4 ● 5 ○ 6 ○ 7 ○ 8 ○ 9

CR = 0% OK

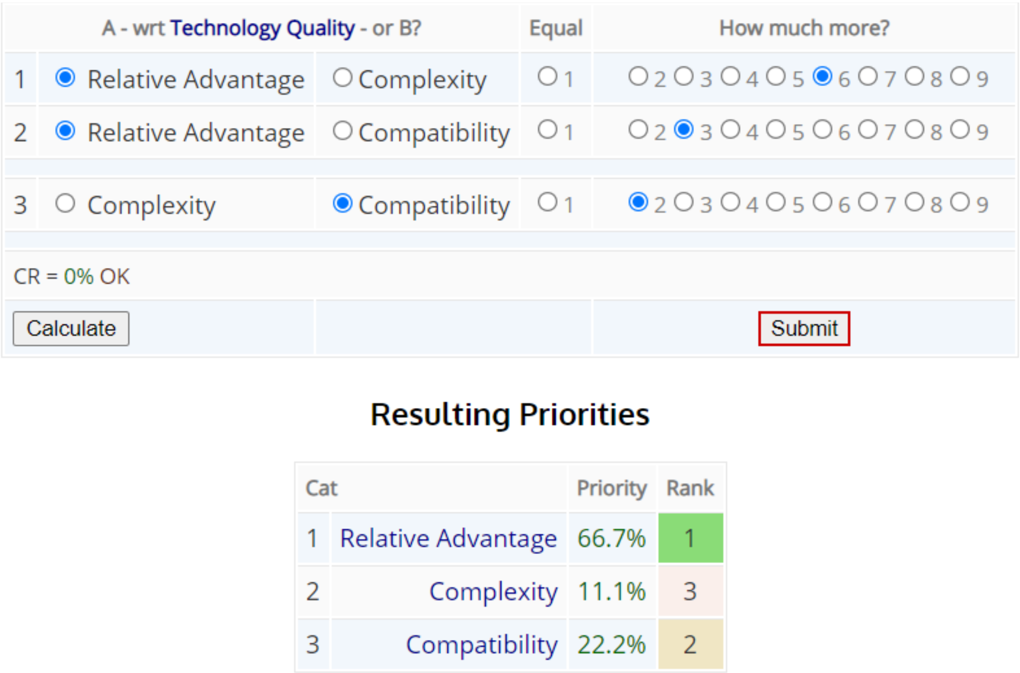
Resulting Priorities

Cat		Priority	Rank
1	Internal Pressure	16.7%	2
2	External Pressure	83.3%	1

Figure 7.10: EC components - AHP pairwise comparison

8.1.1.4 Cluster Four: Technology Quality

The fourth-ranked category of factors that influence BIM adoption within Nigerian SMAFs is *technology quality,* with a 0.067 (06.7%) degree of importance, as shown in Figure 7.7. However, Figure 7.11 shows the ranking of the components for *technology quality* and indicates that *relative advantage* has the highest priority with a 66.7% degree of importance. The second-ranked component is *compatibility,* with a priority result of 22.2%. The lowest-ranked was *complexity,* with a relative importance of 11.1%.



	A - wrt **Technology Quality** - or B?		Equal	How much more?
1	● Relative Advantage	○ Complexity	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ● 6 ○ 7 ○ 8 ○ 9
2	● Relative Advantage	○ Compatibility	○ 1	○ 2 ● 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
3	○ Complexity	● Compatibility	○ 1	● 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9

CR = 0% OK

Resulting Priorities

	Cat	Priority	Rank
1	Relative Advantage	66.7%	1
2	Complexity	11.1%	3
3	Compatibility	22.2%	2

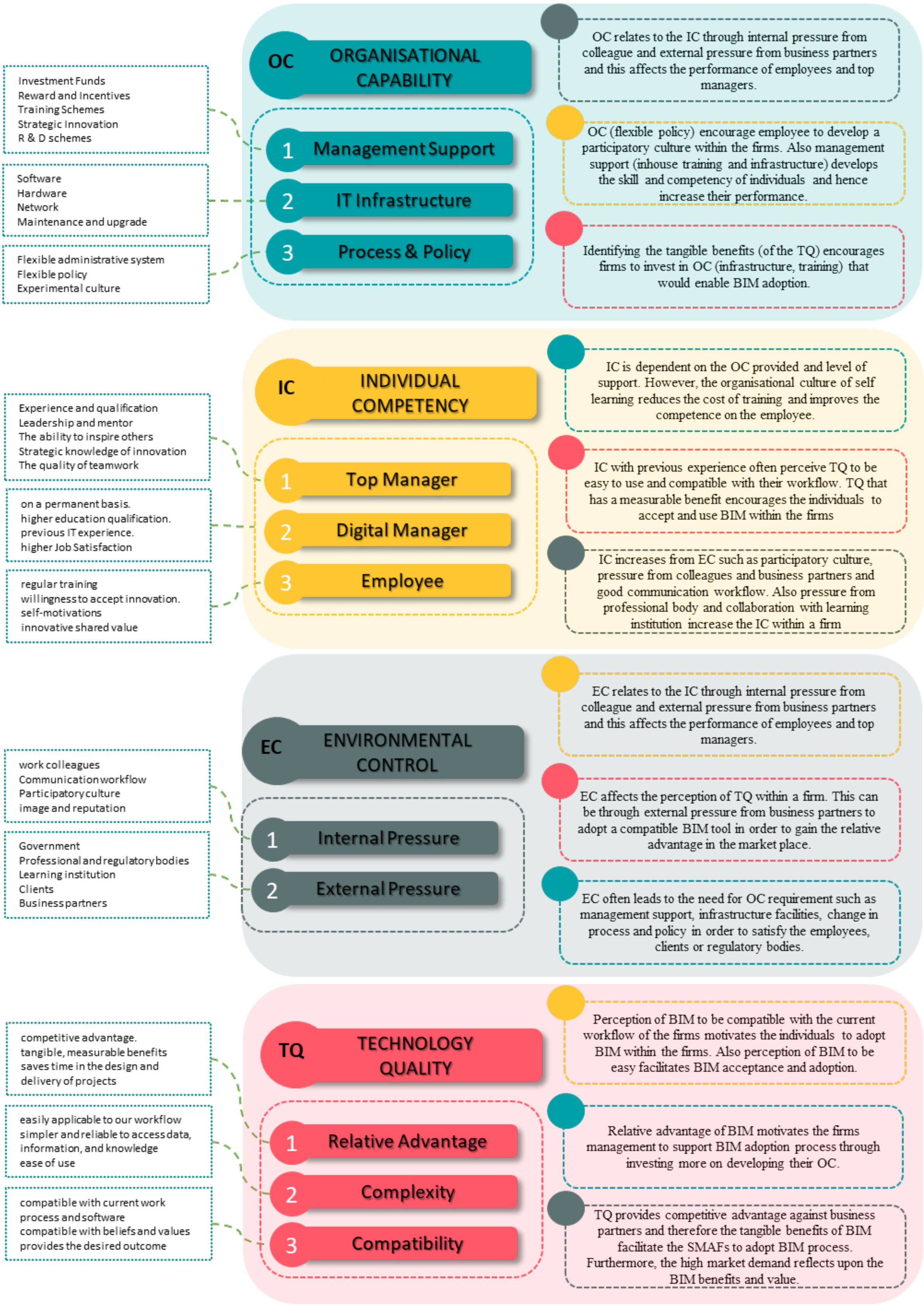
Figure 7.11: TQ components - AHP pairwise comparison

7.5 Stage 3: Developing the proposed BIMAF for Nigerian SMAF

After prioritising the elements within the BIMAC, the next stage is developing the proposed BIMAF for Nigerian SMAFs. As highlighted earlier, the structure of the framework consists of the BIMAC and the BIMAP (see section 7.3). Therefore, the proposed BIMAF for Nigerian SMAFs will be introduced by describing the BIMAC and the BIMAP in the subsequent sections.

7.5.1 Formulation of the BIMAC

This section presents the structure of the BIMAC. Figure 7.4 shows a sample of the structure regarding the priority of the categories, components, and criteria. This was adopted to develop the BIMAF after establishing the rank and priorities of the categories, components, and criteria. A total of four categories and 11 components were ranked using AHP-OS (see section 7.4.5). Accordingly, the criteria for each component were ranked using SEM (see Chapter 0, section 5.7). As a result, these formed the basis for the priority assigned to all elements within the BIMAC. Additionally, the BIMAC is colour coded based on the four main categories (i.e. *organisational capability* represented by ***green***; *individual competence* represented by ***yellow***; *environmental control* represented by ***grey***; and *technology quality* represented by ***red***) to enable the users (i.e. Nigerian SMAFs) of the proposed framework to easily identify the relationship between the categories. In this regard, the subsequent section outlines the proposed BIMAC (as shown in Figure 7.12) based on the relationships established in the presented quantitative interview analysis (see section 6.3).



OC relates to the IC through internal pressure from colleague and external pressure from business partners and this affects the performance of employees and top managers.

OC (flexible policy) encourage employee to develop a participatory culture within the firms. Also management support (inhouse training and infrastructure) develops the skill and competency of individuals and hence increase their performance.

Identifying the tangible benefits (of the TQ) encourages firms to invest in OC (infrastructure, training) that would enable BIM adoption.

IC is dependent on the OC provided and level of support. However, the organisational culture of self learning reduces the cost of training and improves the competence on the employee.

IC with previous experience often perceive TQ to be easy to use and compatible with their workflow. TQ that has a measurable benefit encourages the individuals to accept and use BIM within the firms

IC increases from EC such as participatory culture, pressure from colleagues and business partners and good communication workflow. Also pressure from professional body and collaboration with learning institution increase the IC within a firm

EC relates to the IC through internal pressure from colleague and external pressure from business partners and this affects the performance of employees and top managers.

EC affects the perception of TQ within a firm. This can be through external pressure from business partners to adopt a compatible BIM tool in order to gain the relative advantage in the market place.

EC often leads to the need for OC requirement such as management support, infrastructure facilities, change in process and policy in order to satisfy the employees, clients or regulatory bodies.

Perception of BIM to be compatible with the current workflow of the firms motivates the individuals to adopt BIM within the firms. Also perception of BIM to be easy facilitates BIM acceptance and adoption.

Relative advantage of BIM motivates the firms management to support BIM adoption process through investing more on developing their OC.

TQ provides competitive advantage against business partners and therefore the tangible benefits of BIM facilitate the SMAFs to adopt BIM process. Furthermore, the high market demand reflects upon the BIM benefits and value.

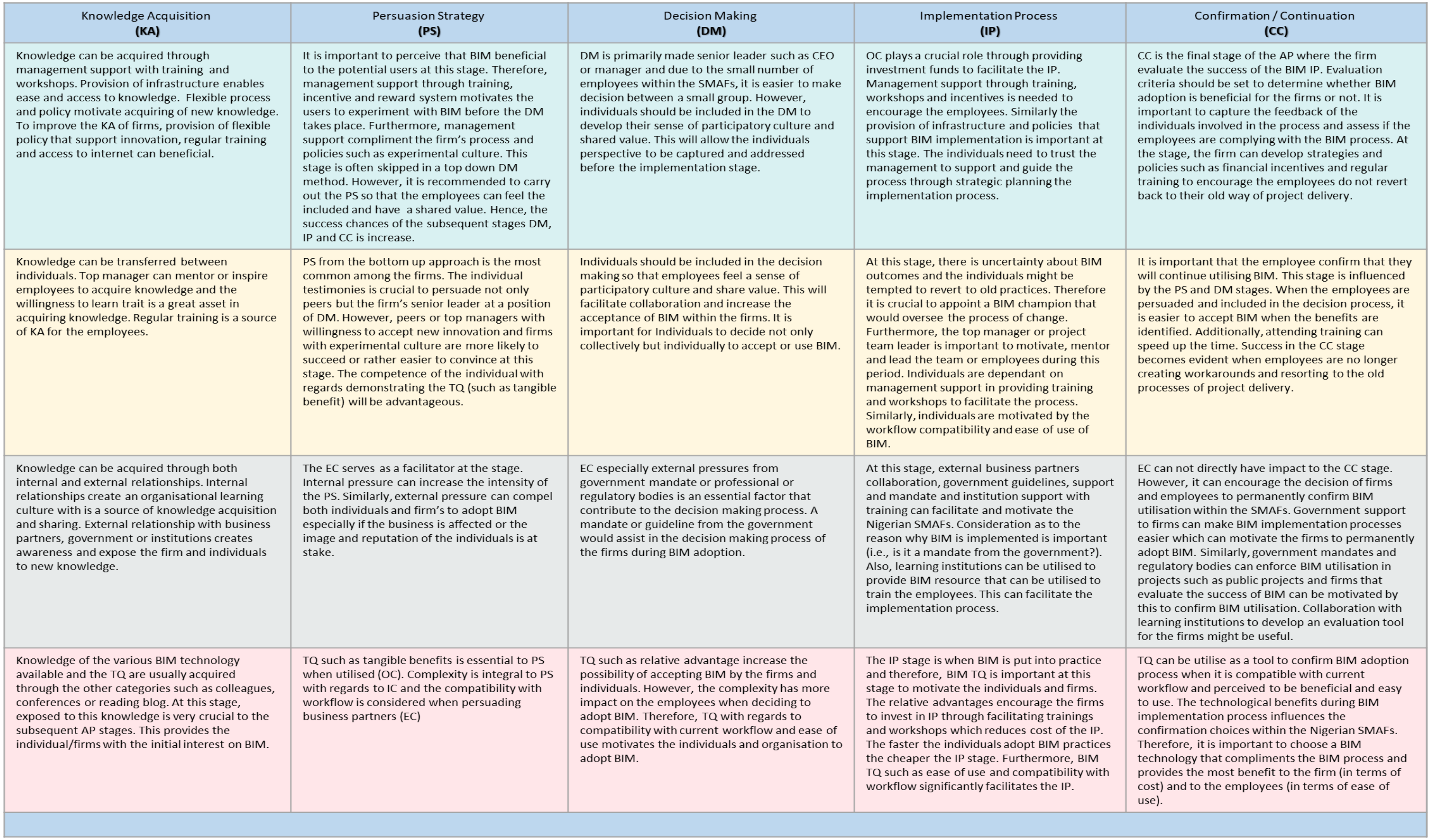
Figure 7.12: The proposed BIMAC

Consequently, Figure 7.12 shows the proposed BIMAC, where the left-hand side of the diagram shows the ranking criteria for each of the 11 components, as discussed in section 7.4 (also see Figure 7.4). For example, IT infrastructure, which was ranked as the second most important component under the organisation capability category, has four criteria (i.e. software, hardware, network, maintenance & upgrade facilities), which are ranked according to their level of importance. Similarly, the ranked components based on their priority are presented under their associated ranked category. For example, the category of organisational capability, which was ranked as the highest level of importance, has components such as management support, IT infrastructure, and process & policy, which are ranked from the highest to the lowest, respectively.

However, on the right-hand side of the BIMAC, the relationships between the categories are presented. For example, the organisational capability category (which is green) has relationships with the other categories, such as environmental control, individual competence, and technology quality (as indicated by grey, yellow, and red colour codes, respectively).

7.5.2 Formulation of the BIMAP

After the BIMAC formulation, this section presents the formulation process of the BIMAP. From Chapter 0 (see section 6.2.3), the BIM adoption process consists of five stages, including knowledge acquisition (*KA*), persuasion strategy (*PS*), decision making (*DM*), implementation process (*IP*), and confirmation of continuation stage (*CC*). These five stages are adopted as the BIMAP main sections. However, to further provide context for the adoption process of BIM within Nigerian SMAFs, the five BIMAP sections relate to each of the four categories of the BIMAC. A discussion on the relationship between the five BIM adoption processes and BIMAC was elicited from the discussion on the qualitative interview analysis (see section 6.3). In this regard, the proposed BIMAP for the framework is presented in Figure 7.13. It shows the five BIM adoption processes in the vertical columns, and the associated four categories of the BIMAC in the horizontal rows, i.e. the first row to the last row are *OC*, *IC, EC,* and *TQ,* respectively.



Knowledge Acquisition **(KA)**	Persuasion Strategy **(PS)**	Decision Making **(DM)**	Implementation Process **(IP)**	Confirmation / Continuation **(CC)**
Knowledge can be acquired through management support with training and workshops. Provision of infrastructure enables ease and access to knowledge. Flexible process and policy motivate acquiring of new knowledge. To improve the KA of firms, provision of flexible policy that support innovation, regular training and access to internet can beneficial.	It is important to perceive that BIM beneficial to the potential users at this stage. Therefore, management support through training, incentive and reward system motivates the users to experiment with BIM before the DM takes place. Furthermore, management support compliment the firm's process and policies such as experimental culture. This stage is often skipped in a top down DM method. However, it is recommended to carry out the PS so that the employees can feel the included and have a shared value. Hence, the success chances of the subsequent stages DM, IP and CC is increase.	DM is primarily made senior leader such as CEO or manager and due to the small number of employees within the SMAFs, it is easier to make decision between a small group. However, individuals should be included in the DM to develop their sense of participatory culture and shared value. This will allow the individuals perspective to be captured and addressed before the implementation stage.	OC plays a crucial role through providing investment funds to facilitate the IP. Management support through training, workshops and incentives is needed to encourage the employees. Similarly the provision of infrastructure and policies that support BIM implementation is important at this stage. The individuals need to trust the management to support and guide the process through strategic planning the implementation process.	CC is the final stage of the AP where the firm evaluate the success of the BIM IP. Evaluation criteria should be set to determine whether BIM adoption is beneficial for the firms or not. It is important to capture the feedback of the individuals involved in the process and assess if the employees are complying with the BIM process. At the stage, the firm can develop strategies and policies such as financial incentives and regular training to encourage the employees do not revert back to their old way of project delivery.
Knowledge can be transferred between individuals. Top manager can mentor or inspire employees to acquire knowledge and the willingness to learn trait is a great asset in acquiring knowledge. Regular training is a source of KA for the employees.	PS from the bottom up approach is the most common among the firms. The individual testimonies is crucial to persuade not only peers but the firm's senior leader at a position of DM. However, peers or top managers with willingness to accept new innovation and firms with experimental culture are more likely to succeed or rather easier to convince at this stage. The competence of the individual with regards demonstrating the TQ (such as tangible benefit) will be advantageous.	Individuals should be included in the decision making so that employees feel a sense of participatory culture and share value. This will facilitate collaboration and increase the acceptance of BIM within the firms. It is important for Individuals to decide not only collectively but individually to accept or use BIM.	At this stage, there is uncertainty about BIM outcomes and the individuals might be tempted to revert to old practices. Therefore it is crucial to appoint a BIM champion that would oversee the process of change. Furthermore, the top manager or project team leader is important to motivate, mentor and lead the team or employees during this period. Individuals are dependant on management support in providing training and workshops to facilitate the process. Similarly, individuals are motivated by the workflow compatibility and ease of use of BIM.	It is important that the employee confirm that they will continue utilising BIM. This stage is influenced by the PS and DM stages. When the employees are persuaded and included in the decision process, it is easier to accept BIM when the benefits are identified. Additionally, attending training can speed up the time. Success in the CC stage becomes evident when employees are no longer creating workarounds and resorting to the old processes of project delivery.
Knowledge can be acquired through both internal and external relationships. Internal relationships create an organisational learning culture with is a source of knowledge acquisition and sharing. External relationship with business partners, government or institutions creates awareness and expose the firm and individuals to new knowledge.	The EC serves as a facilitator at the stage. Internal pressure can increase the intensity of the PS. Similarly, external pressure can compel both individuals and firm's to adopt BIM especially if the business is affected or the image and reputation of the individuals is at stake.	EC especially external pressures from government mandate or professional or regulatory bodies is an essential factor that contribute to the decision making process. A mandate or guideline from the government would assist in the decision making process of the firms during BIM adoption.	At this stage, external business partners collaboration, government guidelines, support and mandate and institution support with training can facilitate and motivate the Nigerian SMAFs. Consideration as to the reason why BIM is implemented is important (i.e., is it a mandate from the government?). Also, learning institutions can be utilised to provide BIM resource that can be utilised to train the employees. This can facilitate the implementation process.	EC can not directly have impact to the CC stage. However, it can encourage the decision of firms and employees to permanently confirm BIM utilisation within the SMAFs. Government support to firms can make BIM implementation processes easier which can motivate the firms to permanently adopt BIM. Similarly, government mandates and regulatory bodies can enforce BIM utilisation in projects such as public projects and firms that evaluate the success of BIM can be motivated by this to confirm BIM utilisation. Collaboration with learning institutions to develop an evaluation tool for the firms might be useful.
Knowledge of the various BIM technology available and the TQ are usually acquired through the other categories such as colleagues, conferences or reading blog. At this stage, exposed to this knowledge is very crucial to the subsequent AP stages. This provides the individual/firms with the initial interest on BIM.	TQ such as tangible benefits is essential to PS when utilised (OC). Complexity is integral to PS with regards to IC and the compatibility with workflow is considered when persuading business partners (EC)	TQ such as relative advantage increase the possibility of accepting BIM by the firms and individuals. However, the complexity has more impact on the employees when deciding to adopt BIM. Therefore, TQ with regards to compatibility with current workflow and ease of use motivates the individuals and organisation to adopt BIM.	The IP stage is when BIM is put into practice and therefore, BIM TQ is important at this stage to motivate the individuals and firms. The relative advantages encourage the firms to invest in IP through facilitating trainings and workshops which reduces cost of the IP. The faster the individuals adopt BIM practices the cheaper the IP stage. Furthermore, BIM TQ such as ease of use and compatibility with workflow significantly facilitates the IP.	TQ can be utilise as a tool to confirm BIM adoption process when it is compatible with current workflow and perceived to be beneficial and easy to use. The technological benefits during BIM implementation process influences the confirmation choices within the Nigerian SMAFs. Therefore, it is important to choose a BIM technology that compliments the BIM process and provides the most benefit to the firm (in terms of cost) and to the employees (in terms of ease of use).

Figure 7.13: The proposed BIMAP

7.6 Stage 4: Creating an Interactive Digital Prototype of the BIMAF.

Prototyping is vital to software development, and UX (user experience) prototyping tools can make the process much more manageable (Li et al., 2021). Therefore, designers, developers, and project managers can communicate with one another to bring ideas to life. Furthermore, prototypes can assist with ideation, map user flows, and communicate progress to stakeholders or clients without writing a single line of code. It is an ideal way to test out ideas and determine how users respond (Makarfi & Underwood, 2021). Thus, prototyping is an ideal way to develop an interactive digital prototype BIMAF for Nigerian SMAFs and facilitates the potential application and usage of the proposed framework through digital application to help validate the framework and digital application.

Garreth et al. (2021) recommended stages of prototype development, including research, planning, wireframe design, coding, publishing, and testing. However, this research adopted the three recommended prototype development stages, as shown in Figure 7.14. First is the research and planning phase, where the available prototyping tools are highlighted, and the initial considerations and practicalities are established. The second phase is the wireframe design, where the framework User Interface (UI) design, pages and content are created and organised. The third phase is the prototype coding, where the UI pages and the core features of the prototype are programmed. The fourth stage is prototype testing, where the framework prototype is generated, published, and shared with users to evaluate and provide feedback.

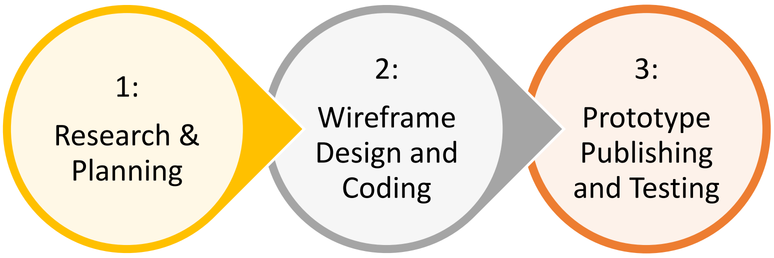


Figure 7.14: Development process of the BIMAF prototype

7.6.1 Research and Planning

The first stage of developing a prototype for the framework is to highlight the requirements through proper planning and researching prototyping tools. It is also essential to establish the selection criteria for the prototype tool. Therefore, the aim of the prototype in this research is to enable users to easily understand the framework and explore its usage as a digital prototype application.

8.1.1.5 Selection Criteria for the Prototyping Tool

Numerous tools are available for UI and UX design prototyping that enables designers to mock-up their ideas, such as Figma, InVision, Sketch, Marvel, Proto.io, Adobe XD, Origami Studio Balsamiq, Principle, Justinmind, Axure RP, and Webflow. However, the initial considerations and practicalities when selecting the prototype tool include the available budget, time constraints, fidelity, the learning curve of the prototype tool, available community/resources, and the available platforms supported.

8.1.1.6 Budget and Time

It is essential to determine and consider what is realistically achievable within the available budget and time. During this research, and due to limited funds and time, the author assigned a preference to cost-effective tools (i.e. tools that are free or offer trial periods). It was also decided that the prototype should only include the core features needed for the framework to be operated and evaluated due to the time constraint.

8.1.1.7 Fidelity and Learning Curve

High fidelity prototypes generate quality feedback on issues, such as the clarity of the information presented, than low-fidelity prototypes, such as paper prototypes, and are therefore more suitable for the design refinement process (Li et al., 2021; Benyon et al., 2005; Brinck et al., 2002). High-fidelity prototypes make usability evaluations and identify issues easier as they are “running systems” that allow the user to navigate different areas of the framework (Nielsen, 2011). However, developing a high-fidelity prototype might take a long period of time when the learning curve of the tool is difficult. Therefore, it is essential to consider tools with an easier learning curve due to the time constraint of this research.

8.1.1.8 Community and Resources

For this research, prototyping tools with a large community tend to have more online resources, such as plugins, templates, and learning content. Therefore, community and resource availability were a consideration for selecting the prototyping tool utilised during the development stage.

8.1.1.9 Supported Platforms

Prototyping tools that provide web and desktop versions (PC/Mac) are preferable for the development of the BIMAC prototype stage because they provide the flexibility to work on multiple devices and locations. Additionally, prototyping tools, such as Figma, Adobe XD, Sketch, Marvel and Proto.io, that support sharing with mobile devices, such as Android or iOS, are preferable when publishing and sharing the BIMAC prototype with users.

8.1.1.10 Adopted Prototyping Tool Justification

Based on the selection criteria considered when choosing a prototyping tool for this research, the four shortlisted tools were: InVision (version dated February 20, 2020), Sketch (v63.1), Figma (version dated February 27, 2020), and Adobe XD (version dated February 10, 2020). However, Table 7.3 shows that Figma best satisfied the criteria and, therefore, was deemed appropriate. Figma is a tool that offers an interactive graphic user interface platform for UX/UI design, which requires no programming skills. The easy learning curve of Figma makes it desirable for newbies, unlike Adobe XD. Also, Table 7.3 shows that only Figma has web-based support that can be accessed on a PC/Mac, unlike sketch, which is only available on Mac. Additionally, Figma can be published to run on mobile devices (Android and iOS) for users to evaluate and provide feedback. Furthermore, three free projects can be created and published in collaboration with team members without any financial cost, unlike InVision. Above all, Figma has a large support community and open-source resources, such as plugins and templates, making it easier to find support/solutions to issues when needed. Having selected the tool for adoption, the next step is to develop the wireframe design for the framework prototype.

Table 7.3: Selection Criteria

Name	Version Date	Price	Platforms	Skill Required
InVision	February 20, 2020	Free	Mac OS, Windows	Medium
Sketch	v63.1	$99	Mac OS	High
Figma	February 27, 2020	Free	Mac OS, Windows, Web	Medium
Adobe XD	February 10, 2020	Free	Mac OS, Windows	High

7.6.2 Wireframe Design

The term wireframe has been used interchangeably with various terms, including sketch, mock-up, storyboard, and prototype; however, wireframe is the typical term used in relation to the sketching layouts of websites (Adams, 2020). Wireframing is important for the design and creation of products, specifically websites and applications, because it keeps those involved in the design process (e.g. designers, developers, clients) up-to-date and clear on the design plan for the product (Bank, 2014). Wireframes are also beneficial because they can be updated quickly in a collaborative environment, and mistakes can be corrected throughout the many versions allowed (Van der Lelie, 2006). Another important part of the wireframing process is the identification of who will be using a website and for what reasons (Schewe & Thalheim, 2010). In this research context, the wireframe design would be used to develop the BIMAF prototype for Nigerian SMAFs.

The wireframe design process starts with sketching a site map or page layout that displays in a basic chart where each page exists within the whole of the application prototype; it also details how any actions lead to a new page (Vitols et al., 2011; Yang et al., 2016). The visuals of a sitemap/layout typically include rectangles representing a page, while a diamond represents an action or decision with arrows guiding designers through the flow of the pages (Hamm, 2014). Figure 7.15 shows an example of the initial 2D wireframe sketches of the page layouts. These sketches enabled the articulation of the content of each page and the position of the information and icons. It also presented the connection between the pages and how they link to each other.

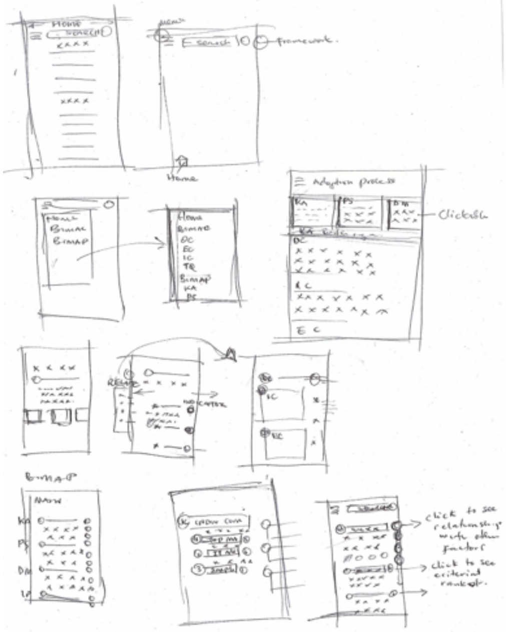


Figure 7.15: 2D wireframe sketch of the page layouts

Furthermore, a high-fidelity wireframe is designed using the initial sketch as a guide. The higher the fidelity, the easier the wireframe design can be programmed for being interactive. Figure 7.16 shows a screenshot of the completed wireframe design for the BIMAF prototype. However, before developing the high-fidelity wireframe, the platform on which the prototype will be published and tested needs to be considered because that is what determines the size of the frames. For example, in this prototype design, although the prototype can be evaluated with the available web version, it was optimised for Android devices with a screen size of 360mm x 640mm, such as the Google Pixel Nexus 5. Furthermore, the BIMAF prototype wireframe design consists of the content, structure, action buttons, colour pallet and navigation icons, as shown in Figure 7.16.

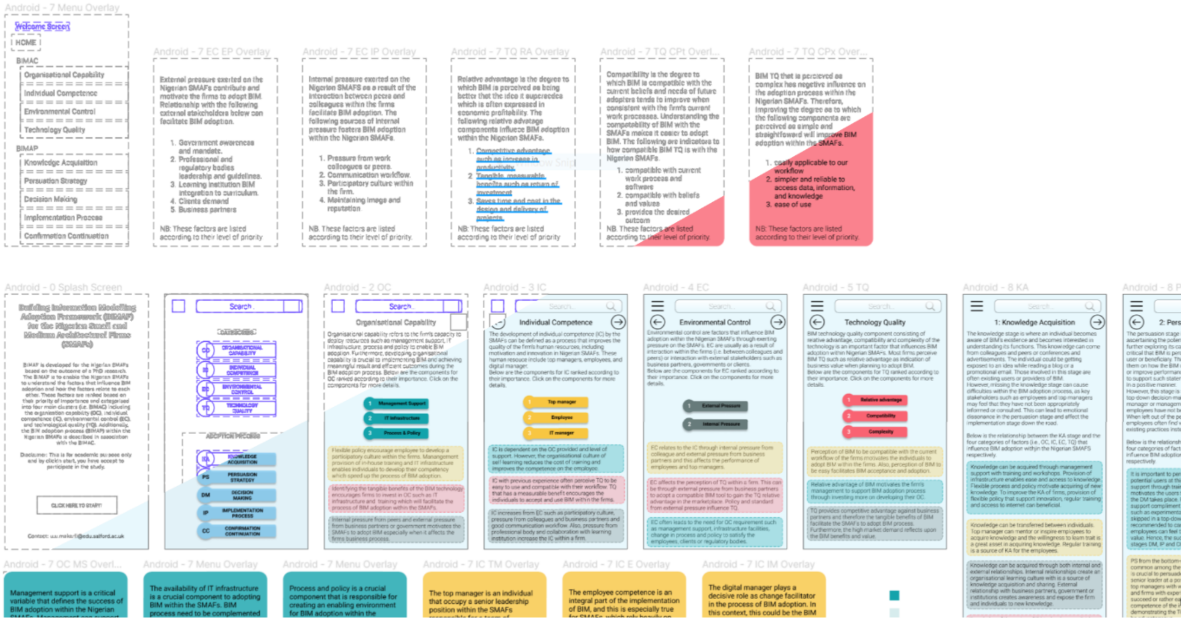


Figure 7.16: BIMAF wireframe design

The next stage after the wireframe design is the coding process, which involves programming the prototype interaction. This contributes to the user experience when evaluating the BIMAF prototype. Essential considerations at this stage are the flow of the pages, how the navigation icons link to each other, the animation when an action is activated, and the display of overlaid pages. In Figure 7.17, the screenshot of the coded wireframe diagram shows the relationship between each action button. A light blue connecting line denotes the relationship between the frames. Each connection is configured with the action required when activated, such as animation styles, delays, and display positions of the next frame.

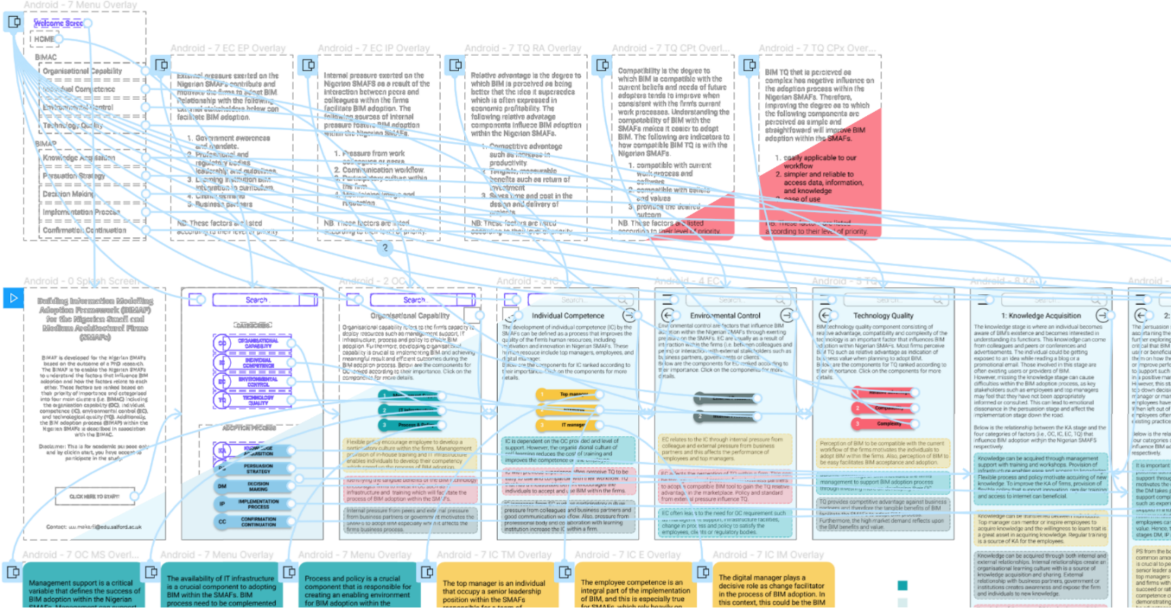


Figure 7.17: BIMAF wireframe coding

7.6.3 Prototype Testing

This user design evaluation can begin once a more detailed wireframe is created, and users can pretend they are interacting with it (Canziba, 2018). In this research, the BIMAF prototype primarily supports a web version where a link and barcode are generated and shared with users to test and provide feedback (see Table 7.4).

Table 7.4: Barcode of the prototype BIMAF web and Android versions

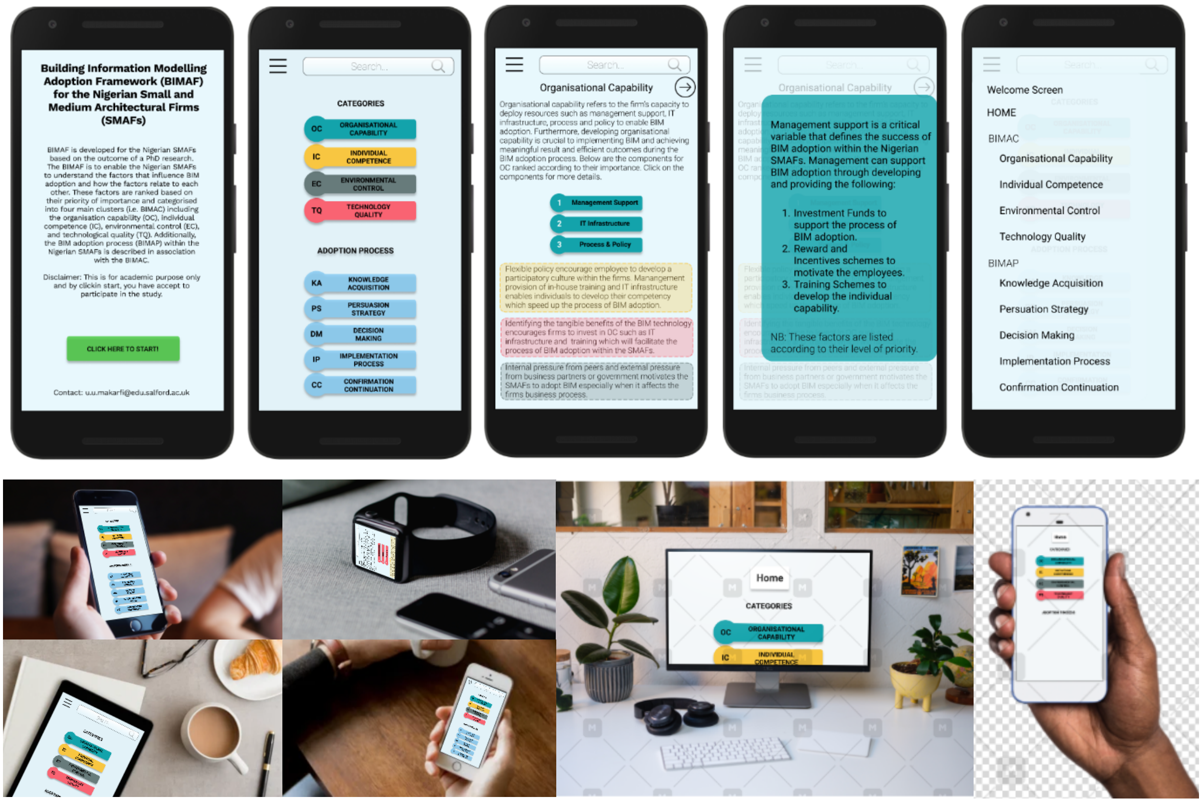
Web Version	Mobile Version
http://tiny.cc/web-bimaf	http://tiny.cc/apkbimaf

However, additional requirements to support Android devices were made when the Figma prototype was exported to Bravo Studio, which is a web-based platform that allows wireframe prototypes from applications, such as Figma, to be developed into an executable mobile application (see Figure 7.18). Once the process of compiling the program was completed, the APK file generated was stored via Google Cloud

Services, and a link and barcode to download the APK was generated (Table 7.4). The link and barcode were subsequently shared with participants, at which point their feedback was collected. Table 7.4 shows the barcode of the web version (left) and the barcode for the Android version (right), which can be accessed by scanning the barcode with devices that have a barcode scanner.

Additionally, Figure 7.18 shows the mock-up of the application prototype, BIMAF. The bottom row shows a mock-up of the application used on multiple platforms, such as mobile devices, desktop PC/Mac and tablets, while the top row shows five example screenshots of the prototype BIMAF used on a mobile device. From the top left, the first screenshot shows the app's landing page and contains an explanation of the app and how to use it. To start using the app, the user must accept the consent disclaimer by clicking the start button at the bottom of the screen. The second image presents the home page where the factor categories (OC, IC, EC, and TQ) and adoption process stages. Users can skip to different sections by selecting the icon of the section. The third screenshot shows an example of the *OC* page selected in which an explanation of the category is presented.

Furthermore, the components within the *OC,* such as management support, IT infrastructure, and process and policy, are presented on their level of importance. However, below the components is information about how the OC relates to the other categories of factors (i.e. *IC*, *EC*, and *TQ*). The fourth screenshot from the top left displays further information about management support, such as the definition and criteria, which is displayed by selecting the management support icon from the *OC* page. The fifth screenshot from the top left shows the menu options, including a quick access icon to all the sections, including the home page and welcome screen (i.e. landing page). This is accessed by selecting the three horizontal stroke icons displayed on the top left of each page. This allows users to quickly access information from a different category by starting from the landing page.



Building Information Modelling Adoption Framework (BIMAF) for the Nigerian Small and Medium Architectural Firms (SMAFs)

BIMAF is developed for the Nigerian SMAFs based on the outcome of a PhD research. The BIMAF is to enable the Nigerian SMAFs to understand the factors that influence BIM adoption and how the factors relate to each other. These factors are ranked based on their priority of importance and categorised into four main clusters (i.e. BIMAC) including the organisation capability (OC), individual competence (IC), environmental control (EC), and technological quality (TQ). Additionally, the BIM adoption process (BIMAP) within the Nigerian SMAFs is described in association with the BIMAC.

Disclaimer: This is for academic purpose only and by clickin start, you have accept to participate in the study.

Contact: u.u.makarfi@edu.salford.ac.uk

Organisational Capability

Organisational capability refers to the firm's capacity to deploy resources such as management support, IT infrastructure, process and policy to enable BIM adoption. Furthermore, developing organisational capability is crucial to implementing BIM and achieving meaningful result and efficient outcomes during the BIM adoption process. Below are the components for OC ranked according to their importance. Click on the components for more details.

Flexible policy encourage employee to develop a participatory culture within the firms. Manangement provision of in-house training and IT infrastructure enables individuals to develop their competency which speed up the process of BIM adoption.

Identifying the tangible benefits of the BIM technology encourages firms to invest in OC such as IT infrastructure and training which will facilitate the process of BIM adoption within the SMAFs.

Internal pressure from peers and external pressure from business partners or government motivates the SMAFs to adopt BIM especially when it affects the firms business process.

Management support is a critical variable that defines the success of BIM adoption within the Nigerian SMAFs. Management can support BIM adoption through developing and providing the following:

1. Investment Funds to support the process of BIM adoption.
2. Reward and Incentives schemes to motivate the employees.
3. Training Schemes to develop the individual capability.

NB: These factors are listed according to their level of priority.

Figure 7.18: BIMAF prototype mock-up

7.7 Framework Validation Process

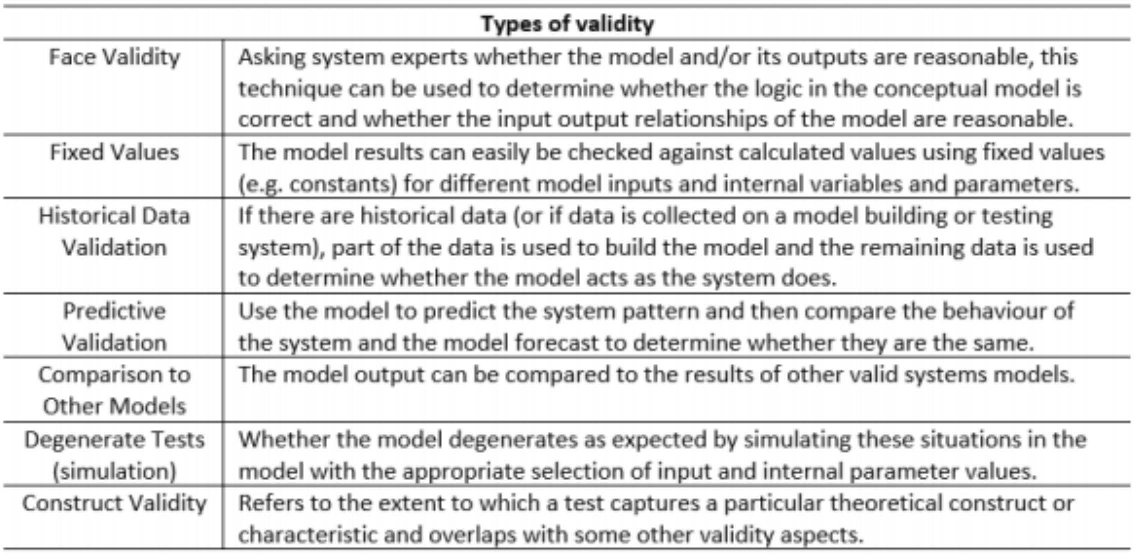
This section presents the validation process of the BIMAF for Nigerian SMAFs. The validation phase is an important aspect of the BIMAF development process since it enhances the amount of evidence and confirms the framework's trustworthiness (Kennedy et al., 2005). Additionally, the validation process is appropriate for confirming the usefulness, generality, and implementability of the proposed BIMAF (Frees, 1996). Furthermore, validity should be determined internally and externally. In this regard, Creswell (2007) highlighted that internal validity examines whether the outcomes reported in research are attributable to the modification of the independent variable rather than another cause (i.e. the independent variable and dependent variable have a causal relationship), while external validity relates to the extent to which the research findings may be generalised to other locations (ecological validity), across time (historical validity), and/or to other people (population validity). In the context of this research, internal validation was addressed by: (i) carefully selecting participants who met the research sample criteria and (ii) conducting a validity test using Cronbach's alpha. Similarly, external validation was obtained by conducting a large-scale online survey that included a diverse spectrum of professionals within Nigerian SMAFs. Furthermore, the validation process could be extended to determine whether the BIMAF's outputs are sufficiently accurate for the intended purpose, as Sargent (1998) suggested. This could be achieved using the concept of UX/UI as demonstrated in studies with similar context (Makarfi, 2022). Therefore, the validation process aims to checking the "operational validity" process rather than achieve absolute validity. In this regard, the subsequent sections present the validation technique adopted, validation criteria, validation process, and validation outputs.

7.7.1 The Validation Technique Adopted

The nature of the framework and its analysis of real-world entities is the primary determinant of a strategy to validate a framework (Bell et al., 2018; Gass, 1983). Furthermore, the validation techniques defined in the body of literature (Bell et al., 2018; Creswell, 2018; Gass, 1993; Kennedy et al., 2005; Sargent, 1998) can be used either subjectively or objectively described in Table 7.5.

Table 7.5: Framework Validation Techniques

Adapted from Bell et al. (2018)



Types of validity	
Face Validity	Asking system experts whether the model and/or its outputs are reasonable, this technique can be used to determine whether the logic in the conceptual model is correct and whether the input output relationships of the model are reasonable.
Fixed Values	The model results can easily be checked against calculated values using fixed values (e.g. constants) for different model inputs and internal variables and parameters.
Historical Data Validation	If there are historical data (or if data is collected on a model building or testing system), part of the data is used to build the model and the remaining data is used to determine whether the model acts as the system does.
Predictive Validation	Use the model to predict the system pattern and then compare the behaviour of the system and the model forecast to determine whether they are the same.
Comparison to Other Models	The model output can be compared to the results of other valid systems models.
Degenerate Tests (simulation)	Whether the model degenerates as expected by simulating these situations in the model with the appropriate selection of input and internal parameter values.
Construct Validity	Refers to the extent to which a test captures a particular theoretical construct or characteristic and overlaps with some other validity aspects.

The framework validation techniques highlighted in Table 7.5 show that the nature of the research determines the appropriate validation technique. For example, *fixed values* and *comparison to other models* require the outcome of the research (i.e., model or framework) to be checked against another valid model or framework. Similarly, *Predictive Validation* and *Degenerate Tests* are appropriate for studies involving simulation through testing different situations based on specific inputs or parameters. *Historical data validation* requires the segregation of data were part of the data is used to develop the model or framework while the other part is used to test the model or framework. On the other hand, *construct validity* refers to the extent to which a test captures a theoretical construct. However, *face validity*, which is a technique of asking experts in the subject whether the output, logic, and relationship between the factors of the model or framework (i.e., digital BIMAF prototype) are reasonable, seemed appropriate for validating the developed BIMAF, which aims to provide an understanding of the process of BIM adoption within Nigerian SMAFs. This decision can be rationalised as the study's ultimate goal of validating the proposed BIMAF for industry-wide application. The three validation options considered include: (i) the focus group, (ii) the interview, and (iii) surveys. According to Creswell & Creswell (2018), qualitative interviews enable the researcher to conduct unstructured interviews with participants face-to-face, over the internet or telephone, or in focus groups with six to eight individuals per group. These interviews consist of a few open-ended questions to gather the participants' thoughts, ideas, and feedback. However, the benefits of interviews include flexibility and the ability to clarify interviewees' doubts, as opposed to the lack of flexibility and the restrictive nature of questionnaires in terms of lack of communication with participants (Saunders, Lewis & Thornhill, 2019). Additionally, conducting focus group exercises might be difficult due to the researcher's constraints on time, funds, and the global pandemic (i.e. travel restrictions and the slow response of participants). Therefore, interviews were deemed the most appropriate option based on the aforementioned circumstances.

7.7.2 The Validation Criteria

Semi-structured interviews were used to conduct rigorous validation, which allowed the researcher to maximise the amount and depth of information acquired during the interview session and cover the necessary questions, as proposed by Creswell (2018). The interviews were designed to cover the thesis's significant contributions to knowledge and practice, such as the factors influencing BIM adoption within Nigerian SMAFs. Furthermore, the interviews allowed participants to provide further recommendations (either specific or more general) based on their perception of the framework. However, to validate the framework, the interviews were guided by a set of criteria. Bell et al. (2018), Gass (1983), and Reed et al. (2006) suggested criteria for evaluating the following validity and reliability of the framework:

(i) Comprehension,
(ii) Precision,
(iii) Applicability, and
(iv) Feasibility.

Similarly, Frees (1996) proposed including the following three pragmatic criteria for framework validation: generality, usefulness, and implementability. However, Kiviniemi (2005) stated that there is no objective method to measure and validate the usefulness or generality of a framework. In this regard, while contextualising the validity and reliability process of the proposed BIMAF for Nigerian SMAFs, the following criteria are set out based on authors, such as Bell et al. (2018), Gass (1983) and Reed et al. (2006).

(i) **Comprehension**: whether the framework is *clear* and *understandable*.
(ii) **Usefulness**: whether the framework is *beneficial* to the target audience.
(iii) **Feasibility**: whether the framework is *practical* and can be *implemented*.
(iv) **Generality**: whether the framework is *applicable*, *relevant*, and *fits* the context.

7.7.3 The Validation Method

As discussed in the previous section (see section 7.7), while conducting the empirical study, several steps were employed to ensure internal and external validity (i.e. through conducting a large-scale online survey). However, to increase the credibility of the proposed BIMAF for Nigerian SMAFs, an additional validation process was conducted through semi-structured interviews with five experts from the industry. In this regard, participants familiar with the BIM adoption process were chosen from professionals and experts within Nigerian SMAFs.

The interview process involved the following steps: (i) an instruction/introduction to the BIMAF for Nigerian SMAF participants; (ii) participants were subsequently presented with the prototype of the proposed BIMAF, including the overall initial diagram; and (iii) participants were asked to assess the proposed BIMAF based on the validation criteria. Participants were provided with instructions on using the framework and a general overview of the validation process. However, the response time of the participants ranged from a few hours to a day. Furthermore, to ensure that participants were fully familiar with the prototype and to ensure a credible assessment of the prototype, the duration for providing feedback and recommendations was flexible and not specified. Moreover, the exercise was carried out online due to unforeseen circumstances, namely COVID travel restrictions due to the global pandemic. At the end of the exercise, the data collected from the semi-structured interview process was analysed using thematic analysis and the outcome is presented in the subsequent sections.

7.7.4 The Validation of the Results and Outcome

The purpose of the validation interviews was to validate the proposed BIMAF for Nigerian SMAFs as developed in the previous sections (sections 7.5 and 7.6) in relation to comprehension, usefulness, feasibility, and generality. The following section presents the outcome of the validation result based on the validation criteria.

Comprehension

The researcher investigated whether the framework was comprehensive, useful, feasible and could be generalised, as previously described (section 7.7.2). Firstly, the comprehensiveness of the framework was evaluated by asking the validators *whether the framework is clear, understandable, and precise or accurate*. Based on their responses, V03 avowed that the framework is easy to understand and highlighted that the colour code associated with the four categories is among the best feature of the framework.

> "I like the way you used colours to separate each category. This makes it easier to understand which category is discussed" (V03)

Similarly, V05 affirmed that the framework is easily understandable and positively endorsed the concept, particularly the amount of information presented and how the factors relate to each other. This shows that although the framework is comprehensive, it is also presented in a way that the validators find easy to read and understandable.

> "I actually like the app. You can easily understand the connections and relationships between all the factors… and there are a lot of factors in which have further explanations to them when you click. It is a good concept" (V05)

Although the overall response to the comprehensiveness of the framework was positive, V01 made suggestions on how to increase the clarity of the framework. Suggestions by V01 include the addition of each criterion definition used within the framework.

> "I believe that providing a clear definition for each criterion you used in the framework will be extremely beneficial; this will tremendously the firms or users in understanding the BIM framework and adoption process" (V01).

Usefulness

Secondly, the usefulness of the framework was investigated. To achieve this, the validators were asked their opinion on the usefulness of the framework. In this regard, the validators considered the framework beneficial to Nigerian SMAFs and expressed that it not only shows the factors to consider when adopting BIM but also ranks and categorises them based on their priority. Additionally, V04 stated that the user could easily identify and consider factors based on their priority, which implies that the framework would aid SMAFs in making an informed decision when considering the factors that influence BIM adoption within their firms.

> "It is very good that you have categories and sections. It makes it easier to know the factors under the organisation or individual, and since they are ranked, you can easily know which one needs more consideration." (V04)

Furthermore, V02 acknowledged the rigour of the framework and added that it could be useful for Nigerian SMAFs. Therefore, Nigerian SMAFs would save time, effort and cost on researching the factors and processes involved in BIM adoption. This shows that the framework is beneficial and valuable and fits the context of the study.

> "It looks very broad and rigorous. I don't think I have any recommendations. The categories and factors seemed balanced a critically analysed and linked. This can be applicable in different firms and it saves [the] firm the time to research and understand the adoption process and factors involved in BIM adoption." (V02)

Additionally, V03 attested to the accuracy of the information presented within the framework and was particularly interested in the environmental control category and its relation to the BIM adoption process.

> "I think the category of the environmental control is very important, especially during the five stages of adoption process. It is accurately captured, and I agree with the information reported." (V03)

Feasibility

The third criterion for validating the framework was exploring the feasibility of the framework with regard to its practicality and implementability. The validators confirmed that they found the framework feasible. However, V02 stated that the framework could be graded as moderately feasible, as it has yet to be applied in practice.

> "Moderately […] from the framework, it is feasible, and the outcome of its application could prove such" (V02)

Similarly, V01 highlighted that the framework is feasible and can be used as a guide when implementing BIM within Nigerian SMAFs. Furthermore, V01 suggested that the framework could benefit from an additional assessment section for firms based on the presented categories while acknowledging this research scope. Therefore, in addition to the four categories within the BIMAF, the prototype functionality should be extended to accommodate assessment tools to support SMAF evaluation of their current BIM adoption level. However, this suggestion is beyond the scope of this research, as V01 already acknowledged, and therefore, it was recommended for future research.

> "Although this might be beyond the scope of your research, I think [the] framework can benefit from adding a section where the firms can assess their current situation based on the requirement and process presented. That way they can implement the BIM using the framework as a guide." (V01)

Generality

The fourth criterion was the generality of the framework (*"whether the framework is applicable, relevant, and fits the context"*). The overall outcome of the validation process shows that the framework can be generalisable and is relevant to the research area, which is to develop a BIM adoption framework for understanding BIM adoption within Nigerian SMAFs. In this regard, validators *V01*, *V02*, and *V05* believe that the framework is highly generalisable and has the potential to be universally applicable.

> "Highly generalisable […] I believe the framework is designed to have a universal application." (V01)

Similarly, V05 outlines that the app concept for the framework is beneficial to employees, management and professional bodies when trying to understand the adoption of the BIM process within the industry. This indicates that the framework is relevant to Nigerian SMAFs and has valuable potential.

> "I think the app idea is very good because the employees can use it, the management can use it and even the professional bodies can understand the process of BIM adoption and know how they fit in..." (V05)

In addition to the simplistic framework presentation, *V02* reaffirmed that the framework has much value and could potentially impact the building sector. Furthermore, *V02* stated that a similar approach could be used to understanding BIM adoption within other countries and Africa as a whole.

> I am impressed with the framework. The way the information is simplified and presented. It will definitely have a lot of value and impact on the construction industry because [a] similar approach can be used to understand BIM adoption in Nigeria, Africa and other countries. This has the potential of becoming a business idea. (V02)

7.7.5 Overview of the Validation Outcome

The results from the framework validation process indicate that it is meaningful and capable of reflecting the complexity of BIM adoption within Nigerian SMAFs. The developed framework was also endorsed as practical and capable of making a significant impact on Nigerian SMAFs. However, the experts who participated in the validation process suggested additional refinements to the developed BIMAF, which include:

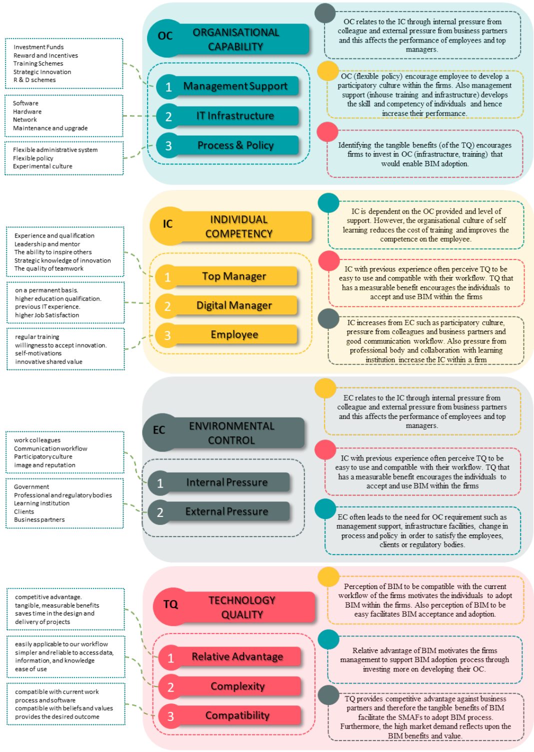
1. Define the factors within the prototype to enable the users to understand what each factor represents and entails. This will provide additional clarity on the factors within the prototype BIMAF.
2. Prepare a guideline of how the framework works to assist users in navigating and understanding the structure and constructs within the prototype BIMAF.
3. Suggest and vividly highlight various incentive strategies at the implementation stage to encourage implementation.
4. Extend the framework by developing an assessment methodology for firms using the framework as a guide.

In response to these findings, the first suggestion was to define the factors within the prototype BIMAF to enable users to develop a clearer understanding of what each entails. A brief description of each of the factors has been included in the digital BIMAF prototype. However, with regards to the second suggestion, which was to prepare a guide on how the framework works, a discussion on this is included in the splash screen (the initial landing page of the prototype app) and presented in the subsequent section. Similarly, the third suggestion to highlight the incentives strategies at the implementation stage to encourage implementation was included in the prototype BIMAF. Finally, the last suggestion to develop an assessment methodology has been considered and added to the recommendation section for further research. Additionally, the assessment methodology for Nigerian SMAFs is beyond the scope of this research, and the time limit would not allow the researcher to accommodate this suggestion into the scope of the study. The subsequent section presents the revised BIMAF (Figure 7.19) and how it works.

7.7.6 How to Use the Prototype BIMAF

The developed BIMAF for SMAFs has two parts: the BIMAC (see section 7.5.1) and the BIMAP (see section 7.5.2). The BIMAC consists of the following four prioritised categories, from the most to the least important: organisational capability (OC), individual competence (IC), environmental control (EC), and technology quality (TQ). Furthermore, these categories have components that are ranked by their level of importance. On the other hand, the BIMAP consists of five adoption processes, namely knowledge acquisition (KA), persuasion strategy (PS), decision making (DM), implementation process (IP), confirmation or continuation (CC), which are defined and described based on the four categories of the BIMAC. However, the first screen displayed on the developed prototype is called the splash screen, which shows a consent page and a summary of what the application entails. Users are required to read and accept the consent before proceeding. The next screen that appears is the home screen, which shows the four categories and the five BIM adoption processes depicting the BIMAC and BIMAP, respectively. Each category leads to the components that are clustered and related to the category. However, the relationship between categories is displayed within the page in a colour-coded style where green means OC related discussion, and yellow depicts the IC related discussion, red shows the TQ related discussion and grey signifies the EC related discussion. Additionally, further information can be accessed by selecting any of the components. For the BIMAP categories, the user can navigate between the five BIM adoption stages through the navigation buttons at the top or through the menu buttons.

The BIMAF digital prototype can be used to understand the process of BIM adoption within Nigerian SMAFs by reading through the processes and factors that influence BIM adoption within Nigerian SMAFs. Therefore, the user is expected to reflect upon the priorities of the factors and their relationships in order to make an informed decision when considering investing in BIM adoption.



OC relates to the IC through internal pressure from colleague and external pressure from business partners and this affects the performance of employees and top managers.

OC (flexible policy) encourage employee to develop a participatory culture within the firms. Also management support (inhouse training and infrastructure) develops the skill and competency of individuals and hence increase their performance.

Identifying the tangible benefits (of the TQ) encourages firms to invest in OC (infrastructure, training) that would enable BIM adoption.

IC is dependent on the OC provided and level of support. However, the organisational culture of self learning reduces the cost of training and improves the competence on the employee.

IC with previous experience often perceive TQ to be easy to use and compatible with their workflow. TQ that has a measurable benefit encourages the individuals to accept and use BIM within the firms

IC increases from EC such as participatory culture, pressure from colleagues and business partners and good communication workflow. Also pressure from professional body and collaboration with learning institution increase the IC within a firm

EC relates to the IC through internal pressure from colleague and external pressure from business partners and this affects the performance of employees and top managers.

IC with previous experience often perceive TQ to be easy to use and compatible with their workflow. TQ that has a measurable benefit encourages the individuals to accept and use BIM within the firms

EC often leads to the need for OC requirement such as management support, infrastructure facilities, change in process and policy in order to satisfy the employees, clients or regulatory bodies.

Perception of BIM to be compatible with the current workflow of the firms motivates the individuals to adopt BIM within the firms. Also perception of BIM to be easy facilitates BIM acceptance and adoption.

Relative advantage of BIM motivates the firms management to support BIM adoption process through investing more on developing their OC.

TQ provides competitive advantage against business partners and therefore the tangible benefits of BIM facilitate the SMAFs to adopt BIM process. Furthermore, the high market demand reflects upon the BIM benefits and value.

Knowledge Acquisition **(KA)**	Persuasion Strategy **(PS)**	Decision Making **(DM)**	Implementation Process **(IP)**	Confirmation / Continuation **(CC)**
Knowledge can be acquired through management support with training and workshops. Provision of infrastructure enables ease and access to knowledge. Flexible process and policy motivate acquiring of new knowledge. To improve the KA of firms, provision of flexible policy that support innovation, regular training and access to internet can beneficial.	It is important to perceive that BIM beneficial to the potential users at this stage. Therefore, management support through training, incentive and reward system motivates the users to experiment with BIM before the DM takes place. Furthermore, management support compliment the firm's process and policies such as experimental culture. This stage is often skipped in a top down DM method. However, it is recommended to carry out the PS so that the employees can feel the included and have a shared value. Hence, the success chances of the subsequent stages DM, IP and CC is increase.	DM is primarily made senior leader such as CEO or manager and due to the small number of employees within the SMAFs, it is easier to make decision between a small group. However, individuals should be included in the DM to develop their sense of participatory culture and shared value. This will allow the individuals perspective to be captured and addressed before the implementation stage.	OC plays a crucial role through providing investment funds to facilitate the IP. Management support through training, workshops and incentives is needed to encourage the employees. Similarly the provision of infrastructure and policies that support BIM implementation is important at this stage. The individuals need to trust the management to support and guide the process through strategic planning the implementation process.	CC is the final stage of the AP where the firm evaluate the success of the BIM IP. Evaluation criteria should be set to determine whether BIM adoption is beneficial for the firms or not. It is important to capture the feedback of the individuals involved in the process and assess if the employees are complying with the BIM process. At the stage, the firm can develop strategies and policies such as financial incentives and regular training to encourage the employees do not revert back to their old way of project delivery.
Knowledge can be transferred between individuals. Top manager can mentor or inspire employees to acquire knowledge and the willingness to learn trait is a great asset in acquiring knowledge. Regular training is a source of KA for the employees.	PS from the bottom up approach is the most common among the firms. The individual testimonies is crucial to persuade not only peers but the firm's senior leader at a position of DM. However, peers or top managers with willingness to accept new innovation and firms with experimental culture are more likely to succeed or rather easier to convince at this stage. The competence of the individual with regards demonstrating the TQ (such as tangible benefit) will be advantageous.	Individuals should be included in the decision making so that employees feel a sense of participatory culture and share value. This will facilitate collaboration and increase the acceptance of BIM within the firms. It is important for Individuals to decide not only collectively but individually to accept or use BIM.	At this stage, there is uncertainty about BIM outcomes and the individuals might be tempted to revert to old practices. Therefore it is crucial to appoint a BIM champion that would oversee the process of change. Furthermore, the top manager or project team leader is important to motivate, mentor and lead the team or employees during this period. Individuals are dependant on management support in providing training and workshops to facilitate the process. Similarly, individuals are motivated by the workflow compatibility and ease of use of BIM.	It is important that the employee confirm that they will continue utilising BIM. This stage is influenced by the PS and DM stages. When the employees are persuaded and included in the decision process, it is easier to accept BIM when the benefits are identified. Additionally, attending training can speed up the time. Success in the CC stage becomes evident when employees are no longer creating workarounds and resorting to the old processes of project delivery.
Knowledge can be acquired through both internal and external relationships. Internal relationships create an organisational learning culture with is a source of knowledge acquisition and sharing. External relationship with business partners, government or institutions creates awareness and expose the firm and individuals to new knowledge.	The EC serves as a facilitator at the stage. Internal pressure can increase the intensity of the PS. Similarly, external pressure can compel both individuals and firm's to adopt BIM especially if the business is affected or the image and reputation of the individuals is at stake.	EC especially external pressures from government mandate or professional or regulatory bodies is an essential factor that contribute to the decision making process. A mandate or guideline from the government would assist in the decision making process of the firms during BIM adoption.	At this stage, external business partners collaboration, government guidelines, support and mandate and institution support with training can facilitate and motivate the Nigerian SMAFs. Consideration as to the reason why BIM is implemented is important (i.e., is it a mandate from the government?). Also, learning institutions can be utilised to provide BIM resource that can be utilised to train the employees. This can facilitate the implementation process.	EC can not directly have impact to the CC stage. However, it can encourage the decision of firms and employees to permanently confirm BIM utilisation within the SMAFs. Government support to firms can make BIM implementation processes easier which can motivate the firms to permanently adopt BIM. Similarly, government mandates and regulatory bodies can enforce BIM utilisation in projects such as public projects and firms that evaluate the success of BIM can be motivated by this to confirm BIM utilisation. Collaboration with learning institutions to develop an evaluation tool for the firms might be useful.
Knowledge of the various BIM technology available and the TQ are usually acquired through the other categories such as colleagues, conferences or reading blog. At this stage, exposed to this knowledge is very crucial to the subsequent AP stages. This provides the individual/firms with the initial interest on BIM.	TQ such as tangible benefits is essential to PS when utilised (OC). Complexity is integral to PS with regards to IC and the compatibility with workflow is considered when persuading business partners (EC)	TQ such as relative advantage increase the possibility of accepting BIM by the firms and individuals. However, the complexity has more impact on the employees when deciding to adopt BIM. Therefore, TQ with regards to compatibility with current workflow and ease of use motivates the individuals and organisation to adopt BIM.	The IP stage is when BIM is put into practice and therefore, BIM TQ is important at this stage to motivate the individuals and firms. The relative advantages encourage the firms to invest in IP through facilitating trainings and workshops which reduces cost of the IP. The faster the individuals adopt BIM practices the cheaper the IP stage. Furthermore, BIM TQ such as ease of use and compatibility with workflow significantly facilitates the IP.	TQ can be utilise as a tool to confirm BIM adoption process when it is compatible with current workflow and perceived to be beneficial and easy to use. The technological benefits during BIM implementation process influences the confirmation choices within the Nigerian SMAFs. Therefore, it is important to choose a BIM technology that compliments the BIM process and provides the most benefit to the firm (in terms of cost) and to the employees (in terms of ease of use).
The knowledge stage is where an individual becomes aware of BIM's existence and becomes interested in understanding its functions. This knowledge can come from colleagues and peers or conferences and advertisements. The individual could be getting exposed to an idea while reading a blog or a promotional email. Those involved in this stage are often existing users or providers of BIM. Missing the knowledge stage can cause difficulties within the BIM adoption process, as key stakeholders such as employees and top managers may feel that they have not been appropriately informed or consulted. This can lead to emotional dissonance in the persuasion stage and affect the implementation stage down the road.	The persuasion stage is where the individual is ascertaining the potential value of adopting BIM, and further exploring its capabilities. In this stage, it is critical that BIM is perceived to be useful by the BIM user or beneficiary. This can be done by educating them on how the BIM can save them time, reduce costs or improve performance. Testimonials are a great way to support such statements and alter their perceptions in a positive manner. This stage is sometimes skipped in a top-down decision-making model, when the top manager or management is content with BIM while employees have not been convinced of its usefulness. When left out of the persuasion stage, however, employees often find workarounds to maintain their existing practices instead of adopting new ones.	The decision stage determines whether BIM will be adopted or rejected. This stage will sometimes require a referendum or the participation/input of a top manager or management. Although the final decision making is held by a small group or a single individual, facilitating collaboration helps others feel included in the decision. Once BIM is adopted, each individual will still decide whether they will actually use it, so it is important to bring all stakeholders such as employee and top managers into the decision-making process—at least via a discussion—to make sure they feel included.	The implementation stage is the process of putting BIM into practice. There can still be a degree of uncertainty surrounding the outcomes of BIM and whether to keep it as opposed to reverting backward to old practices. Typically, this stage involves a team with a BIM manager or a dedicated BIM champions to oversee the process. The implementation team needs to consider ways to reduce the cost of BIM adoption, both financially and in terms of energy and mental effort. Facilitating training workshops can significantly help the implementation and reduce switching costs. Ease of use is paramount in the implementation phase. Another way to motivate and encourage people through this stage is sharing testimonials on how BIM has been incorporated into their activities effectively and without undue challenge.	The final stage in the adoption process of BIM is the confirmation stage, where the individual seeks supportive confirmation on their decision. In a BIM methodology, the confirmation stage is simply an evaluation based on whether the criteria initially set up for the project has been met. Success in the confirmation stage becomes evident when people are no longer creating work arounds and resorting to old processes.

Figure 7.19: The proposed BIM adoption framework

7.8 Chapter Summary

In this chapter, the three key areas reported are the development of the framework, the development of the digital prototype of the framework, and the validation of the framework and digital prototype. The results and findings from the quantitative analysis (Chapter 5) and the qualitative analysis chapters (Chapter 6) enabled the synthesis of the BIMAF. The synthesis started with defining the structure of the framework, then the AHP was utilised to prioritise the four categories, and 11 components of the factors were identified and discussed as influential in BIM adoption amongst Nigerian SMAFs (Chapters 6 and 7). The digital prototype was developed as a web-based, and mobile application to: (i) enable Nigerian SMAFs to have easy access to the BIMAF and (ii) facilitate the validation process. The digital prototype was tested and validated before proceeding to the framework validation phase. The BIMAF for Nigerian SMAFs was validated through semi-structured interviews with five experts based on four criteria, namely comprehension, usefulness, feasibility, and generality. The outcome of the validation process demonstrated that the developed BIMAF was clear, understandable and could be easily applied with a substantial range of benefits to Nigerian SMAFs. Finally, the feedback from the validation process was utilised to improve the framework, gather some recommendations, and inform future research.

8 Chapter Eight – Conclusion & Recommendations

8.1 Chapter Overview

In the previous chapter, the BIM adoption framework and digital prototype were developed and validated. This chapter starts with the research conclusion remarks, which summarises the research journey. Next, the attainment of the research objectives is discussed; these were outlined at the beginning of the research and focused on achieving the aim of the study. Furthermore, the contributions are highlighted based on the theoretical and practical contributions of the research. Additionally, the limitations of the study are acknowledged, and recommendations for further study are presented. Finally, a summary of the chapter is presented. Thus, the chapter encapsulates the concluding remarks and the overview of the research journey.

8.2 Concluding Remarks

The construction industry plays a significant role in the development of a nation's economy. According to Farmer (2016), the construction industry has been associated with a lack of productivity and inefficiency in project delivery due to the fragmented nature of the industry and ineffective coordination between stakeholders involved in the construction process. Therefore, there is a need to adopt innovative processes to alleviate or mitigate the challenges within the construction industry.

Traditionally, the process of creating and managing information when delivering a project is usually linear and fragmented. It typically starts with the architect translating the client's brief and producing the actual architectural design. The architect then involves other professionals, such as structural, mechanical, and electrical engineers, who design engineering drawings (structural, electrical, and mechanical) using the architectural design as a reference. However, since the designs are fragmented, it makes it challenging to detect clashes and errors. In situations where the engineer submits engineering designs to the architect and technical errors are not identified until the construction phase, an iterative process ensues, which involves contact with engineers to clarify amendments to the engineering designs. This iterative process makes it difficult to meet the deadline and results in project delays which incur additional costs. Therefore, in a traditional project delivery process, the information generated is disjointed, and the process can be time-consuming due to unidentified errors, the linear flow of information, and poor communication channels, which directly impact the cost of delivery. However, Building Information Modelling (BIM) addresses the issues associated with the traditional approach. BIM is the process of creating and managing information about a construction project across the project life cycle by using a model that contains graphical and non-graphical information/data. BIM is a collaborative project delivery process where all stakeholders are involved in developing a BIM model, a single digital repository product that contains all the information generated and needed for the project. The synchronisation of all design information and processes makes BIM more beneficial across all project delivery phases (i.e. design, construction, maintenance, and decommission/demolition) than the traditional process.

In the Nigerian Construction Industry, Small and Medium Architectural Firms (SMAFs) form the majority of the workforce. However, unlike large firms, SMAFs have limited capacity to absorb the costs associated with BIM adoption. Therefore, there is resistance to BIM adoption and the need to understand its process within the SMAFs to enable them to prioritise and manage their limited resources. This need prompted the research questions: (i) How would the BIM adoption process be analysed and understood to increase the level of BIM adoption within Nigerian SMAFs? (ii) What are the key factors that influence BIM adoption within Nigerian SMAFs? (iii) To what extent do these key factors influence the BIM adoption process within Nigerian SMAFs (i.e. the priorities and relationship of the key factors to the BIM adoption process)?

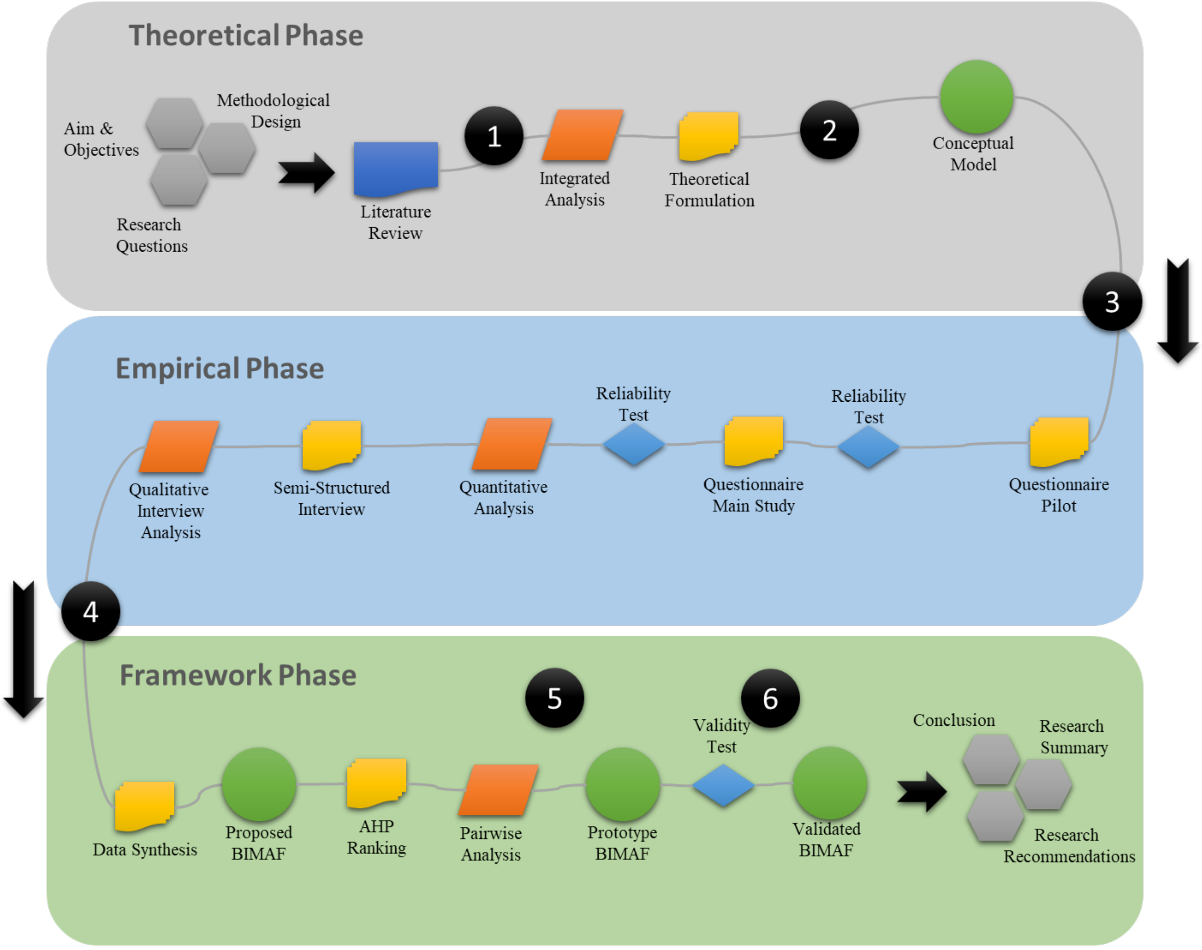


Figure 8.1: Research Journey Diagram

In this regard, the research set out a research design that included a nine-stage process clustered into three phases (i.e., the theoretical phase, empirical phase, and framework phase) to address the main aim of the research, which is to develop a framework for BIM adoption within Nigerian SMAFs that enables them to understand the BIM adoption process and make informed decisions when prioritising limited resources. As shown in Figure 8.1, the theoretical phase included literature, theory formulation, and conceptual model development. The empirical phase included data collection, data analysis, and data synthesis. The framework phase included framework development, prototype development and framework validation.

Considering the above, the theoretical phase of the research commenced by exploring the current state of the Nigerian construction industry, which discussed the characteristics and importance of the industry with a specific focus on the current challenges and need for improvement within the industry. This linked with the introduction of the concept of BIM, which reviewed its dimensions, maturity levels, application, drivers/benefits, barriers/challenges. These are crucial considerations to understanding the adoption of BIM. Furthermore, in a global context, BIM adoption and standards and the current adoption process within the Nigerian context are explored. The outcome of this review justified the need for the adoption of BIM within Nigeria. The second stage of the theoretical phase focused on the evaluation of the prevailing BIM-related models, frameworks, and theories.

The outcome of these stages was leveraged to develop the conceptual model for this research. The conceptual model defined the constructs and explained how the components and their associated indicators influenced the BIM adoption process. The conceptual model consists of 11 components clustered into four categories, namely organisational capability (OC), individual competence (IC), environmental control (EC) and technology quality (TQ). The OC refers to the firm’s capacity to deploy resources such as management support, IT infrastructure, and process and policy. The IC refers to the process of improving the quality of the firm’s human resources, such as the top manager, digital manager, and employees. The EC refers to the impact of internal pressure, such as colleagues, peers, and superiors, and external factors, such as professional business partners, government, clients, learning institutions, and regulatory bodies, on BIM adoption within Nigerian SMAFs. The TQ refers to the characteristics of the technology used to deliver, deploy, or author BIM, such as the relative advantages, compatibility, and complexity. After the identification of the construct used in developing the conceptual model, the subsequent stage is the empirical phase.

In the empirical phase, the empirical evaluation of the conceptual model and the key factors that influence BIM adoption within the Nigerian context was established. The empirical phase commenced by identifying the most appropriate methodological strategies for the study. When identifying the appropriate methodological strategy, three important questions are: what the research philosophical stance is, what the chosen research methodology is, and how are the chosen methods. The empirical enquiry adopted a two-step process (i.e. exploratory sequential method), which involves a quantitative questionnaire survey and a qualitative semi-structured interview. The first step was a quantitative survey which validated and established empirical evidence of the conceptual model through structural equation model analysis with AMOS statistical software. The results of the SEM analysis presented the relationship and hierarchy between the indicators of the 11 components that influence BIM adoption. The outcome of the quantitative study paved the way for the qualitative study, which was the second step. The qualitative interview presented the understanding of BIM and the adoption process within Nigerian SMAFS. This was achieved through an in-depth analysis and discussion of the factors that influence BIM adoption, which was considered under the four main categories (OC, IC, EC, and TQ). Thus, the empirical phase was crucial to: (i) validate the conceptual model and provide empirical evidence of the factors that influence BIM adoption within Nigerian SMAFs; (ii) establish the relationships between the key factors that influence BIM adoption within Nigerian SMAFs; (iii) enable the process of developing the proposed BIM adoption framework for Nigerian SMAFs.

The framework was the third phase of the research design and consisted of three stages (i.e. the framework development, prototype development, and validation process). The framework development process started by establishing the structure of the framework for BIM adoption, called BIMAF. Based on the framework structure, the proposed BIMAF consists of two components: the BIM adoption component (BIMAC) and the BIM adoption process (BIMAP). BIMAC includes the key factors influencing BIM adoption within Nigerian SMAFs, clustered into four categories, 11 components and their associated indicators. Additionally, the priorities of the components and categories of the factors that influence BIM adoption within Nigerian SMAFs were analysed and determined through the Analytical Hierarchical Process (AHP). The AHP was conducted through a pairwise comparison exercise with ten experts familiar with the subject area (BIM in Nigeria). Secondly, in the BIMAP section, the four categories (i.e. *OC, IC, EC*, and *TQ*) are mapped onto the BIM adoption process stages in a matrix arrangement. The stages of the BIM adoption process are knowledge acquisition, persuasion strategy, decision making, implementation process, and continuation or confirmation. Furthermore, the BIMAF was developed into a digital prototype application and validated.

The next step of the framework phase was to develop the digital prototype to validate the framework and enable BIMAF users (i.e. Nigerian SMAFs) to understand the BIM adoption process easily. The digital prototype development process consisted of three stages (i.e. research and planning, wireframe design, and prototype testing). The research and planning stage discussed the selection criteria for the tools needed to develop the prototype user interface (UI) and user experience (UX). The criteria considered included budget, cost, time, community, resources, learning curve, and compatible platforms. Considering these criteria, Figma was established as the most appropriate and, therefore, was selected from the four shortlisted tools. Having selected the tool, the wireframe design process started with a paper-based sketch to design and specify the page layout, interactions, buttons and icons. This was translated into a digital version using Figma. Furthermore, the wireframe design was compiled and tested by publishing a web and mobile version of the prototype. Additionally, a link and QR code for both prototype versions were generated and shared with validators during the validation process.

The validation process assessed the prototype BIMAF framework's operational validity. The validity criteria for the process considered the comprehensiveness, usefulness, feasibility, and generality of the prototype BIMAF. The process involved five experts, and the overall outcome was positive. Thus, the framework development phase presented a final, validated prototype framework, which led to the synthesis of the research objectives, limitations of the research, and recommendations for further study, as presented in the following sections.

8.3 Synthesis of the Research Objectives

In order to achieve the aim of the research, six objectives were set out at the beginning of this study. Therefore, the discussions on how each research objective is attained are presented in the subsequent sections.

8.3.1 Attainment of Research Objective One

To explore the current state of the art of the Nigerian construction industry and BIM.

The study's first objective was to explore the current state of the art of the Nigerian construction industry and BIM. This objective was achieved through a two-fold comprehensive literature review. The first part of the literature review related to the Nigerian construction industry (NCI), which provided an insight into its nature and the challenges within the industry. The outcome of the first part of the review established the importance of the NCI to the development of the nation's economy and the need to improve standards and productivity within the industry, particularly when delivering projects. Among the notable challenges hampering the industry, as identified in the literature, are substandard construction data, poor policies and performance, low productivity, inadequate regulations, limited technical skills, limited access to funds, delays in project delivery and a high level of project failures. However, the first part of the literature review concluded the need to shift to a more effective and efficient project delivery method and practice.

The second part of the literature review explored the current state of the art of BIM in the global context and Nigeria. The literature established the definition, concept, applications, dimensions, potential benefits and associated challenges of BIM. The literature further explored the current state of BIM adoption around the globe, and the different levels of BIM maturity, capability, and standards. In Nigeria, BIM is considered a solution to the challenges associated with the construction industry, particularly the challenges related to project delivery, such as project delays and failure due to the fragmentation of information and communication flow (Akinade et al., 2018; Ebiloma et al., 2017; Sher et al., 2010). Furthermore, frameworks and models related to BIM were evaluated and contextualised to align with this study. Understanding the theories, frameworks, and models related to BIM was crucial to (i) identifying the key factors for consideration when adopting BIM and (ii) developing the conceptual model for the evaluation of the research. Therefore, the next objective was to identify the factors that influence BIM adoption within Nigerian SMAFs.

8.3.2 Attainment of Research Objective Two

To identify the key factors that influence BIM adoption within Nigerian SMAFs.

The second objective, which was to identify the key factors influencing BIM adoption within Nigerian SMAFs, is crucial to developing the conceptual model for evaluating the study. The research aims to develop a framework for understanding BIM within Nigerian SMAFs to equip firms with knowledge of the factors that influence its adoption. Therefore, a comprehensive and systematic literature review related to BIM adoption was carried out to achieve this objective. However, the study began with identifying 11 components clustered under four categories: organisational capability, individual competence, environmental control, and technology quality. These components are understood to influence BIM adoption within Nigerian SMAFs. Furthermore, the organisational capability consists of three components: management support, IT infrastructure, and policy and process.

Similarly, three components are associated with individual competence: the top manager, digital manager, and employee. Environmental control consists of two components: internal pressure and external pressure, while the quality of technology consists of three components, which are relative advantage, compatibility, and complexity. However, through the literature review, these components were further divided into a set of indicators, which total 42 indicators.

Additionally, empirical evidence was collected and analysed through a questionnaire survey and semi-structured interviews to further reinforce the factors identified during the literature review. The design of the questionnaire survey allowed respondents to confirm or reject the factors identified and provided an opportunity for respondents to provide additional factors that are perceived to have an influence on BIM adoption within Nigerian SMAFs. Similarly, the interview survey was flexible enough to confirm and identify key factors that influence BIM adoption within Nigerian SMAFs.

8.3.3 **Attainment of Research Objective Three**

To develop a conceptual model through the identified factors that influence BIM adoption within Nigerian SMAFs.

The conceptual model is a process of developing a graphical representation of the relationships between the constructs and factors that influence BIM adoption, as identified in the literature review. This helps to introduce the conceptual understanding of the construct's terminologies. Considering this, objective three was achieved through synthesising the literature review outcomes concerning the factors influencing BIM adoption, BIM-related models, and frameworks for BIM adoption. Therefore, considering all the information from objectives one and two in a logical manner, the conceptual model considers two core areas, namely the dependent and independent variables. The dependent variables evolved from the review of theories, models, and frameworks that are related to BIM adoption, while the independent variables were elicited from the factors identified in the second objective of the study. Additionally, BIM-related innovation theories were considered as best practice to understand prior research conducted in this area; these included system theories (Chun et al., 2008), system thinking (Chun et al., 2008), diffusion innovation theory (Rogers, 1995) and the technology acceptance model (Davis et al., 1989).

The conceptual model's independent variables comprise four clusters of 11 associated components, which are the factors that influence BIM adoption within Nigerian SMAFs. These clusters include organisational capability (i.e. *management support, IT infrastructure, policy and process*), individual competence (i.e. *top managers, digital managers, and employees*), environmental control (*i.e. internal* *pressure and external pressure*), and technology quality (*relative advantage, compatibility, and complexity*).

Additionally, the conceptual model defined the metrics that explained the theoretical formation of the indicators, components, and categories that served as an evaluation model for the research. Furthermore, the conceptual model served as a guide for the empirical enquiry (i.e. developing the questionnaire survey). Therefore, the development of the conceptual model was essential for evaluating the relationships between key factors that influence BIM adoption and the development of the framework to understand the BIM adoption process amongst Nigerian SMAFs. Considering this, the next objective aimed to evaluate the relationships between the factors within the conceptual model.

8.3.4 **Attainment of Research Objective Four**

To evaluate the relationships between the factors that influence BIM adoption and the adoption process within Nigerian SMAFs

This objective was achieved in two steps, namely through: (i) the analysis of the quantitative questionnaire survey, and (ii) the analysis of the qualitative semi-structured interview. The quantitative questionnaire survey was crucial for capturing the perception of a large number of participants within Nigerian SMAFs. This established empirical evidence of the identified factors to validate the conceptual model. The questionnaire survey was conducted in two steps (i.e. the pilot study and the main study) through an online platform that targeted respondents within Nigerian SMAFs. The survey exercise started with a pilot study that yielded 40 responses. Consequently, the pilot survey was analysed and tested using Cronbach's alpha for construct reliability and internal consistency. The outcome of the analysis proved that the pilot study was reliable, and questions within the questionnaire were adjusted and modified based on the respondents' feedback.

The second part of the survey was analysed using structural equation modelling (SEM), which facilitates the graphical analysis of constructs within a model. The conceptual model was tested for validity, and the relationships between the factors within the conceptual model were also analysed. This outcome of the survey analysis provided the level of influence the factors (i.e. 11 components and their associated indicators) have on BIM adoption within the Nigerian firms, but does not explain the reasons why the factors influence the BIM adoption process within Nigerian SMAFs. In this regard, further understanding of the relationship between the factors and the BIM adoption process was necessary to develop an appropriate framework that captures the BIM adoption process within Nigerian SMAFs. Thus, the outcome of the questionnaire study was explored further through in-depth semi-structured interviews with the 17 participants from Nigerian SMAFs.

The qualitative interview process was the second step to achieving this objective and evaluated the relationships between the factors that influence BIM adoption amongst Nigerian SMAFs. The qualitative semi-structured interview involved 17 professionals from Nigerian SMAFs. The interviews were analysed thematically, and superordinate and subordinate themes were identified from the verbatim transcript. The interview analysis stage started with an overview of the demographics of the participants, such as their size of firms (i.e. micro, small, medium), their BIM maturity level (i.e. level 0, level 1, level 2), the tools predominantly used (i.e. Revit, ArchiCAD, AutoCAD, Sketchup, BIM360, Synchro), and their positions (i.e. CEO, project manager, designer). Additionally, participants' demographics facilitated the understanding of how each cluster differed in their understanding and perception of the factors that influence the BIM adoption process. Overall, the outcome of the qualitative analysis presented an understanding of the BIM adoption process and established an in-depth analysis and discussion of the relationship between each component that influences the BIM adoption process within Nigerian SMAFs. Consequently, the achievement of this objective was essential to achieving the aim of this research (i.e., developing a framework for understanding the BIM adoption process within Nigerian SMAFs.)

8.3.5 Attainment of Research Objective Five

To develop a digital framework for understanding the BIM adoption process within Nigerian SMAFs.

This objective was addressed through a four-step development process that entailed: (i) structuring the framework to fit the aim of the study, namely to develop a BIM adoption framework; (ii) establishing the weighting of the factors that influence BIM adoption (i.e. categories, components, and indicators) to determine their level of priority; (iii) developing the proposed framework that best describes the adoption process of BIM within Nigerian SMAFs, and (iv) creating a digital prototype of the developed framework to ensure Nigerian SMAFs can easily utilise the framework.

In the first step, the BIMAF structure consisted of two sections, which are the BIM adoption categories (BIMAC) and the BIM adoption process (BIMAP). The BIMAC was developed through synthesising the outcome of the data analysis of both the quantitative survey and the qualitative interview. Additionally, the BIMAC section shows the factors (i.e. 11 components with their associated indicators) that influence BIM adoption amongst Nigerian SMAFs and their relationship to each other. However, the BIMAP sections present the BIM adoption process, as emanating from the qualitative interview analysis, within five stages, which are: knowledge acquisition, persuasion strategy, decision making, implementation process, and confirmation or continuation. Within the BIMAC section, these stages are further mapped to the four categories of factors in a matrix structure.

In the second step, an AHP pairwise comparison technique was carried out to prioritise the factors (i.e. the four categories and 11 components) that influence BIM adoption within Nigerian SMAFs; this ranking was based on their level of importance. The AHP was conducted with ten experts, and the data was analysed using online AHP software. Furthermore, the AHP consistency ratio was calculated to validate the reliability of the outcome before accepting the established priorities of the categories and components. Consequently, the ranking of the four categories from the most to least important is: organisation capability, individual competence, environmental control and technology quality. In addition to the priority of the four categories, the components within each category were also established and prioritised.

The third step was to develop a framework that provided an understanding of the BIM adoption process within Nigerian SMAFs. This was addressed by amalgamating the BIMAC and BIMAP to form the BIMAF. The BIMAC consists of four categories that have their own unique colours to facilitate the easy identification of each category. These were utilised when presenting information regarding the relationships between factors of different categories and mapping the BIMAP stages to the categories. A matrix structure was adopted for the BIMAP to make it easy to trace the categories associated with each adoption stage. Overall, the proposed BIMAF consisted of the prioritised factors that influence BIM adoption, their relationships with each other, the BIM adoption process stages, and their relationship with the factors that influence BIM adoption within Nigerian SMAFs. Thus, the proposed BIMAF not only has all the relevant information needed to understand the BIM adoption process within Nigerian SMAFs, but also all relevant information needed to develop an interactive digital prototype.

The final step, which was to develop a digital prototype for the BIMAF, was achieved through a three-step process that comprised research and planning, wireframe design and coding, and prototype publishing and testing. In the research and planning phase, prototyping tools for the user interface (UI) and user experience (UX) were explored and the selection criteria were established. The criteria considered included budget, time, fidelity, learning curve, community, available online resources, and supported platforms. The UI/UX tool selected after considering the criteria was Figma, which offers a free trial, is easy to learn, and supports multiple platforms, including Android/iOS devices, PC, and macOS.

The next phase was the wireframe design, which entailed the development of the mock-ups and sketch layout. In this phase, an initial paper sketch of each page layout, page contents (i.e. the information displayed within each page) and interaction between the icons, buttons, and pages were designed. This was translated into a digital version within the prototype tool and coded. The last stage was to test the prototype through publishing and evaluation. The prototype was converted into a web application and mobile application to ease the process of disseminating the prototype with evaluators, validators, and users. In this regard, a link and QR code were generated and shared with evaluators. The evaluators tested the prototype and, based on their feedback, and the prototype was modified. In this regard, the interactive digital prototype of the BIMAF can be accessed through mobile and desktop devices. The prototype also has a splash screen that provides information on how to use the application. The information includes the purpose of the research, a description of the layout (the BIMAC and the BIMAP), and a consent requirement before users are allowed to interact with the application.

8.3.6 Attainment of Research Objective Six

To validate and propose a final framework that best describes the BIM adoption process within Nigerian SMAFs.

The last objective of the research was to validate the BIMAF, which was achieved through the conduct of small-scale interviews with five BIM experts and professionals within Nigerian SMAFs. However, to confirm that the developed prototype BIMAF had satisfied the research objective, four validation criteria were established, including comprehension (the BIMAF's clarity and precision), usefulness (the perceived benefit to SMAFs), feasibility (the level of practicality and implementability), and generality (its applicability and relevance). Consequently, the validation process started with participant contact, which entailed the provision of the link and barcode of the BIMAF prototype along with a document explaining the nature of the study and the structure of the validation process. This provided validators with an overview of the expectations from the validation exercise. The discussions, suggestions, and recommendations of the validators were collected and analysed to produce the final validated BIMAF for Nigerian SMAFs. Overall, there was a positive endorsement of the prototype BIMAF based on the validation assessment criteria, with a few suggestions that included the need to: define the factors, provide a guideline on how the framework works, and extend the framework to accommodate assessment methodologies. In this regard, the suggestions from the validators based on the outcome of the validation process were considered and addressed accordingly, except the suggestions to expand the prototype BIMAF to accommodate assessment methodologies, as this was considered outside the scope of the scope of this study. However, the suggestion was highlighted in the recommendation for further research.

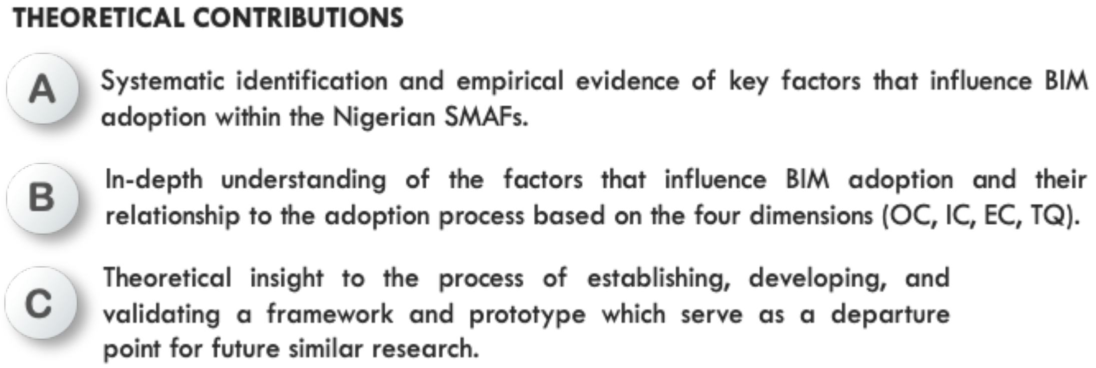
Having discussed the attainment of the six objectives to achieve the aim of this research, the subsequent sections present the knowledge contribution of the study.

8.4 Knowledge Contributions of the Study

The contribution of this research to the existing body of knowledge can be classified into two categories, namely theoretical and practical contributions. Hence, the subsequent sub-sections discuss these two categories.

8.4.1 Theoretical Contribution

The research provides empirical evidence establishing the relationship between key factors, which have been clustered into four main categories (i.e. organisational capability, individual competence, environmental control, and technology quality) and the BIM adoption process within Nigerian SMAFs. However, despite the potential for understanding these relationships, they have not been explored in previous studies. Through this study, the BIM adoption process has been recognised as an innovation, which occurs through the influence of the four main categories of factors. Hence, this study has provided theoretical insight into the BIM adoption process for Nigerian SMAFs by establishing a framework to understand the impact of these key factors on the BIM adoption process as highlighted in Figure 8.2. Furthermore, although the Nigerian context was the focus of the research, the methodology can be applied to the different contexts of emerging markets and/or any study. Thus, a similar study could be undertaken with data from a given context of the emerging market, and the outcome and practical relevance of the study could be as promising as the outcome of this study. Another key contribution of this study is the systematic identification of various key factors through the theoretical phase, which the empirical evidence subsequently established, and the application of the results to the development of a framework. Such systematic identification can be applied to similar contexts of the emerging market or developing countries with similar challenges. A significant contribution to existing knowledge and literature is the application of Structural Equation Modelling (SEM). SEM offers several useful features, especially for modelling multivariate relationships, and there are no alternative methods that are widely used and easily implemented (Mueller & Hancock, 2018; Wang & Wang, 2019). Therefore, the application of SEM promotes better quality research when applying the BIM adoption framework in a firm; this is because several factors influence this process, and SEM has the potential to specify and estimate the relationship between these factors and the adoption process within firms.



THEORETICAL CONTRIBUTIONS

A Systematic identification and empirical evidence of key factors that influence BIM adoption within the Nigerian SMAFs.

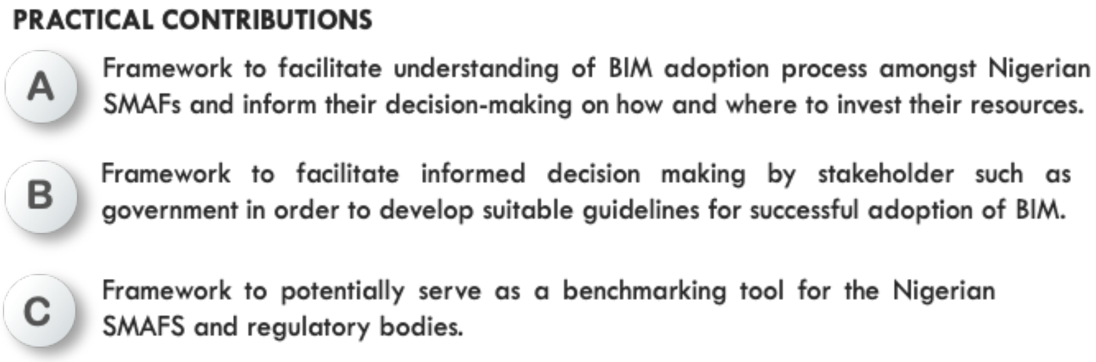
B In-depth understanding of the factors that influence BIM adoption and their relationship to the adoption process based on the four dimensions (OC, IC, EC, TQ).

C Theoretical insight to the process of establishing, developing, and validating a framework and prototype which serve as a departure point for future similar research.

Figure 8.2: Theoretical Contributions

8.4.2 Practical Contribution

The outcome of this research was the development of a framework for understanding BIM adoption within Nigerian SMAFs. Additionally, a digital prototype of the framework was developed, tested and validated by users within Nigerian SMAFs, which provided empirical evidence of the practical impact of the framework on the Nigerian construction industry as summarised in Figure 8.3. In this regard, the framework could facilitate understanding the process of BIM adoption amongst Nigerian SMAFs and inform their decision-making on how and where to invest their resources. Additionally, the framework has the potential to assist SMAFs to prioritise their activities and make strategic decisions based on the different categories of factors identified (organisation capability, individual competence, environmental control, and technological quality). Therefore, decision-makers or/and policymakers such as government bodies and SMAFs are provided with appropriate tools to understand the important considerations needed to develop suitable guidelines for the successful adoption of BIM. Hence, the framework is a direct pathway to developing a holistic strategic framework for BIM adoption, not only for the Nigerian construction industry but for similar emerging markets and developing countries.



PRACTICAL CONTRIBUTIONS

A Framework to facilitate understanding of BIM adoption process amongst Nigerian SMAFs and inform their decision-making on how and where to invest their resources.

B Framework to facilitate informed decision making by stakeholder such as government in order to develop suitable guidelines for successful adoption of BIM.

C Framework to potentially serve as a benchmarking tool for the Nigerian SMAFS and regulatory bodies.

Figure 8.3: Practical Contributions

8.5 Limitations of the Study

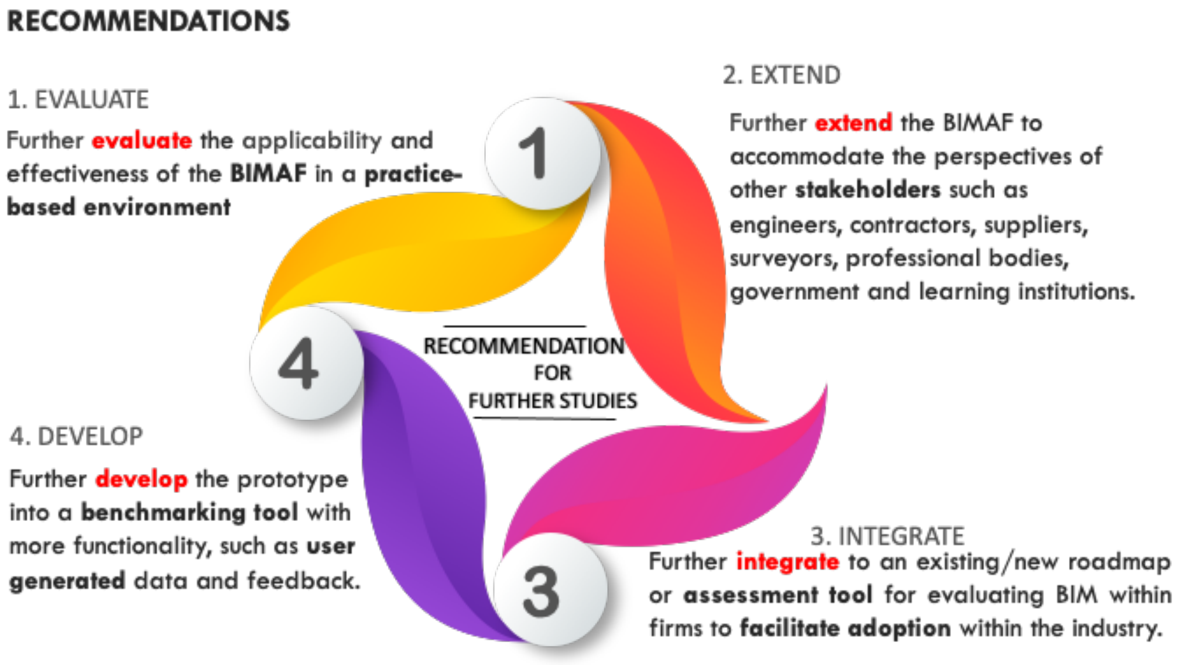
The previous sections discussed how each research objective was achieved. Although the research objectives were met, this section highlights the limitations of the study. In this regard, the limitations considered are:

1. The scope of this study dealt with BIM in the context of the Nigerian construction industry. Although the views of Nigerian SMAFs extended to BIM adoption across the four categories of factors influencing BIM adoption, the views of large firms and professionals, such as engineers, contractors, suppliers, manufacturers, government officials, regulatory bodies and learning institutions, were not included in this study.
2. Additionally, the framework application is limited to the Nigerian construction industry, and larger firms within the industry are not included. Therefore, the framework can be applied to small and medium firms. Similarly, with regards to professionals, the framework is limited to architectural firms.
3. The research was initially intended to validate the digital BIMAF with a focus group to enable access to more in-depth findings. However, due to constraints such as time, financial, and the global COVID-19 pandemic that restricted access and travel, this was not achieved. Notwithstanding, the information collected is valid for the research conclusion.
4. Furthermore, the framework has not been tested and evaluated from the basis of real-world practical scenarios; therefore, it has limitations with regard to its actual application in practice. Nonetheless, these limitations are acknowledged and presented as recommendations for future research.

8.6 Future Research Recommendation

This research developed a BIM adoption framework capable of providing an understanding of the BIM adoption process within Nigerian SMAFs. This framework mapped the relationship between the various factors that influence BIM adoption and the adoption process within Nigerian SMAFs. Although the study successfully prioritises the various factors that influence BIM and develops a prototype of the BIMAF, there is a need to articulate future research areas that emanated as a result of this study as summarised in Figure 8.4. However, considering the research constraints, such as time, resources, scope, and methodology, the following are the recommended future research areas that would build upon the contribution of this study:

1. As mentioned in the limitations, the practical implementation of the BIMAF to establish empirical validation in a practice-based environment is needed. Therefore, further research is recommended to evaluate the applicability and effectiveness of the BIMAF.
2. The BIMAF was developed with information gathered through the lens of practitioners within Nigerian SMAFs. Although the scope of this research was met, it is recommended that the BIMAF should be extended to accommodate the perspectives of other stakeholders/professionals within the construction industry, such as engineers, contractors, suppliers, surveyors, professional bodies, and learning institutions. Thus, using this research as a point of departure, further study could be carried out to extend the BIMAF to understand the BIM adoption process across the wider nation.
3. Furthermore, the BIMAF could be extended through developing or integrating an existing/new roadmap or assessment tool for evaluating BIM within firms to facilitate adoption within the industry. This means that, after understanding the process of adoption, firms can then utilise the BIM adoption roadmap to evaluate and assess their current position and determine the steps needed to fully adopt BIM. Therefore, further research on how to extend the BIMAF to facilitate BIM adoption within the Nigerian industry is recommended.
4. Although a prototype for the BIMAF was developed, it is recommended to develop an application with more functionality, such as the capability for users to comment on various sections of the framework. This would enable Nigerian SMAFs to share their comments and interact with other BIMAF users.



1. EVALUATE

Further **evaluate** the applicability and effectiveness of the **BIMAF** in a **practice-based environment**

2. EXTEND

Further **extend** the BIMAF to accommodate the perspectives of other **stakeholders** such as engineers, contractors, suppliers, surveyors, professional bodies, government and learning institutions.

3. INTEGRATE

Further **integrate** to an existing/new roadmap or **assessment tool** for evaluating BIM within firms to **facilitate adoption** within the industry.

4. DEVELOP

Further **develop** the prototype into a **benchmarking tool** with more functionality, such as **user generated** data and feedback.

Figure 8.4: Future Research Recommendations

8.7 Chapter Summary

This chapter has summarised the research thesis and provided an outline of the accomplishments of its objectives, the contribution to knowledge from the perspectives of both the academic community and practice, the limitations of the findings, and future research. This thesis has achieved the aim of the study, recognising 11 key factors, identifying the BIM adoption process, and mapping the key factors to the BIM adoption process. This has led to the development of a framework for understanding BIM adoption within Nigerian SMAFs. Moreover, this thesis has contributed to knowledge by bridging the gap identified in the literature, namely the limited research available on the BIM adoption process within Nigerian SMAFs. Furthermore, this study has contributed to practice by providing Nigerian SMAFs with a framework and digital prototype capable of describing the BIM adoption process within Nigerian SMAFs and ultimately guiding such organisations through the implementation process.

References

Abd Hamid, A. B., Mohd Taib, M. Z., Abdul Razak, A. H. N., & Embi, M. R. (2018). The Barriers and Causes of Building Information Modelling Usage for Interior Design Industry. *IOP Conference Series: Materials Science and Engineering*, *291*(1), 012002. https://doi.org/10.1088/1757-899X/291/1/012002

Abdulfattah, N. M., Khalafallah, A. M., & Kartam, N. A. (2017). *Lack of BIM Training: Investigating Practical Solutions for the State of Kuwait*. https://doi.org/10.5281/ZENODO.1131846

Abiodun, O., & Nwaogu, J. (2021). Comparative Assessment of Rework on Buildings in Akure Municipal, Ondo State, Nigeria. *International Journal of Sustainable Construction Engineering and Technology*, *12*(2), 24–37.

Abubakar, M., Ibrahim, M. Y., Kado, D., & Kabir, B. (2014). Contractors' Perception of the Factors Affecting Building Information Modelling (BIM) Adoption in the Nigerian Construction Industry. *Computing in Civil and Building Engineering (2014)*, 167–178. https://doi.org/10.1061/9780784413616.022

Adam, V., Manu, P., Mahamadu, A.-M., Dziekonski, K., Kissi, E., Emuze, F., & Lee, S. (2021). Building information modelling (BIM) readiness of construction professionals: the context of the Seychelles construction industry. *Journal of Engineering, Design and Technology*.

Addy, M., Adinyira, E., Ayarkwa, J., Michael, A., Emmanuel, A., & Joshua, A. (2018). Antecedents of building information modelling adoption among quantity surveyors in Ghana: an application of a technology acceptance model. *Journal of Engineering, Design and Technology*, *0*(ja), 0. https://doi.org/doi:10.1108/JEDT-06-2017-0056

Adebakin, I. H., & Ipaye, T. O. (2016). Effect of elevated temperature on the compressive strength of recycled aggregate concrete. *Research Journal of Engineering Sciences*, *5*(9), 1–4.

Adebisi, E. O., Alao, O. O., & Ojo, S. O. (2020). Assessment of early warning signs predisposing building projects to failure in Nigeria. *Journal of Engineering, Design and Technology*.

Adekunle, S., Ejohwomu, O., & Ohis Aigbavboa, C. (2021). *buildings Building Information Modelling Diffusion Research in Developing Countries: A User Meta-Model Approach*. https://doi.org/10.3390/buildings11070264

Agbonlahor, A. A. (2016). Challenges of entrepreneurial education in Nigerian Universities: Towards a repositioning for impact. *Journal of Educational and*

Social Research, *6*(1), 208.

AGC. (2006). *The Associated General Contractors of America*. https://www.engr.psu.edu/ae/thesis/portfolios/2008/tjs288/Research/AGC_GuideToBIM

AGC. (2021). *The Pandemic's Growing Impacts on The Construction Industry: The 2021 Construction Hiring and Business Outlook*. https://www.agc.org/news/2021/01/06/2021-construction-hiring-and-business-outlook

Ahani, A., Rahim, N. Z. A., & Nilashi, M. (2017). Forecasting social CRM adoption in SMEs: A combined SEM-neural network method. *Computers in Human Behavior*, *75*, 560–578. https://doi.org/10.1016/j.chb.2017.05.032

Ahmad, Ibrahim, Price, A. D. F., & Dainty, A. (2006). The analysis and allocation of risks in public private partnerships in infrastructure projects in Nigeria. *Journal of Financial Management of Property and Construction*, *11*(3), 149–164. https://www.emeraldinsight.com/doi/pdfplus/10.1108/13664380680001086

Ahmed, L., & Kassem, M. (2018). A unified BIM adoption taxonomy: Conceptual development, empirical validation and application. *Automation in Construction*, *96*, 103–127. https://doi.org/10.1016/j.autcon.2018.08.017

Ahmed, S. (2018). Barriers to Implementation of Building Information Modeling (BIM) to the Construction Industry: A Review. *Journal of Civil Engineering and Construction*, *7*(2), 107. https://doi.org/10.32732/jcec.2018.7.2.107

Ahmed, S. M., Emam, H. H., & Farrell, P. (2014). Barriers to BIM/4D implementation in Qatar. *The 1st International Conference of Cib Middle East & North Africa Conference*, 533–547.

Ahn, Y. H., Kwak, Y. H., & Suk, S. J. (2016). Contractors' Transformation Strategies for Adopting Building Information Modeling. *Journal of Management in Engineering*, *32*(1), 05015005. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000390

Ahuja, R., Sawhney, A., & Arif, M. (2017). Prioritizing BIM Capabilities of an Organization: An Interpretive Structural Modeling Analysis. *Procedia Engineering*, *196*, 2–10. https://doi.org/10.1016/j.proeng.2017.07.166

Ahuja, R., Sawhney, A., Jain, M., Arif, M., & Rakshit, S. (2018). Factors influencing BIM adoption in emerging markets – the case of India. *International Journal of Construction Management*, 1–12. https://doi.org/10.1080/15623599.2018.1462445

Ahuja, R., Sawhney, A., Jain, M., Arif, M., & Rakshit, S. (2020). Factors influencing BIM adoption in emerging markets–the case of India. *International Journal of Construction Management*, *20*(1), 65–76.

Aibinu, A. A., & Jagboro, G. O. (2002). The effects of construction delays on project delivery in Nigerian construction industry. *International Journal of Project Management*, *20*(8), 593–599. https://doi.org/https://doi.org/10.1016/S0263-7863(02)00028-5

Airbrake. (2017). *What Are Conceptual Models and How Can You Use them?* https://airbrake.io/blog/sdlc/conceptual-model

Aiyetan, A. O. (2018). *Information Communication Technology (ICT) Impact on Building Construction Management Practices in the South West of Nigeria* (pp. 179–187). https://doi.org/10.1007/978-3-319-74123-9_19

Akinade, O. O., Oyedele, L. O., Ajayi, S. O., Bilal, M., Alaka, H. A., Owolabi, H. A., & Arawomo, O. O. (2018). Designing out construction waste using BIM technology: Stakeholders' expectations for industry deployment. *Journal of Cleaner Production*, *180*, 375–385. https://doi.org/10.1016/j.jclepro.2018.01.022

Akintoye, A., & Renukappa, S. (2012). Financing construction projects in developing countries. In *New Perspectives on Construction in Developing Countries* (pp. 345–384). Routledge.

Al-Hammadi, M., & Tian, W. (2020). Challenges and Barriers of Building Information Modeling Adoption in the Saudi Arabian Construction Industry. *The Open Construction & Building Technology Journal*, *14*(1), 98–110. https://doi.org/10.2174/1874836802014010098

Alaneme, G. U., Ezeokpube, G. C., & Mbadike, E. M. (2021). Failure Analysis of a Partially Collapsed Building using Analytical Hierarchical Process. *Journal of Failure Analysis and Prevention*, *21*(1), 160–171.

Alao, O. O., & Jagboro, G. O. (2017). Assessment of causative factors for project abandonment in Nigerian public tertiary educational institutions. *International Journal of Building Pathology and Adaptation*.

Alhusban, M. (2018). *Conceptual procurement framework for building information modelling uptake to enhance buildings' sustainability performance in the Jordanian public sector*. University of Portsmouth.

Ali, M. C. (2014). Exploring the potential of integration quality assessment system in construction (qlassic) with ISO 9001 quality management system (QMS). *International Journal for Quality Research*, *8*(1), 73–86.

Ameyaw, E. E., Hu, Y., Shan, M., Chan, A. P. C., & Le, Y. (2016). *APPLICATION OF DELPHI METHOD IN CONSTRUCTION ENGINEERING AND MANAGEMENT RESEARCH: A QUANTITATIVE PERSPECTIVE*. https://doi.org/10.3846/13923730.2014.945953

Amuda-Yusuf, G. (2018). Critical success factors for building information modelling implementation. *Construction Economics and Building*, *18*(3), 55. https://doi.org/10.5130/AJCEB.v18i3.6000

Angelo, J. G., Sinem, M., Matt, S., Joseph Garcia, A., Mollaoglu, S., & Syal, M. (2018). Implementation of BIM in Small Home-Building Businesses. *Practice Periodical on Structural Design and Construction*, *23*(2), 4018007. https://doi.org/10.1061/(ASCE)SC.1943-5576.0000362

Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C., & O'reilly, K. (2011). Technology adoption in the BIM implementation for lean architectural practice. *Automation in Construction*, *20*(2), 189–195. https://doi.org/10.1016/j.autcon.2010.09.016

Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C., & O'Reilly, K. (2011). BIM adoption and implementation for architectural practices. *Structural Survey*, *29*(1), 7–25. https://doi.org/doi:10.1108/02630801111118377

ARCON. (2017). *Register of registered firms with Architect registration Council of Nigeria (ARCON)*. https://www.arconigeria.org.ng/events/2017-editions-registers-architects-and-architectural-firms

Ardani, J. A., Utomo, C., & Rahmawati, Y. (2021). Model Ownership and Intellectual Property Rights for Collaborative Sustainability on Building Information Modeling. In *Buildings* (Vol. 11, Issue 8). https://doi.org/10.3390/buildings11080346

Aregbeyen, O., & Kolawole, B. O. (2015). Oil revenue, public spending and economic growth relationships in Nigeria. *Journal of Sustainable Development*, *8*(3), 113.

Arpaci, I. (2013). Organizational adoption of mobile communication technologies. *The Department of Information Sistem. School of Informatics of Middle East Technical University*.

Arunkumar, S., Suveetha, V., & Ramesh, A. (2018). A feasibility study on the implementation of building information modeling (BIM): from the architects' & engineers' perspective. *Asian Journal of Civil Engineering*, *19*(2), 239–247. https://doi.org/10.1007/s42107-018-0020-9

Autodesk. (2021). *Building Information Modelling in practice: Autodesk building solutions.* DESIGN & BUILD WITH BIM. https://www.autodesk.com/solutions/bim

Ayinla, K. O., & Adamu, Z. (2018). Bridging the digital divide gap in BIM technology adoption. *Engineering, Construction and Architectural Management*, *25*(10), 1398–1416. https://doi.org/10.1108/ECAM-05-2017-0091

Azam, M. S. (2015). Diffusion of ICT and SME performance. In *Advances in Business Marketing and Purchasing* (Vol. 23A, pp. 7–290). https://doi.org/10.1108/S1069-096420150000023005

Azmi, A., Sapiei, N. S., Mustapha, M. Z., & Abdullah, M. (2016). SMEs' tax compliance costs and IT adoption: the case of a value-added tax. *International Journal of Accounting Information Systems*, *23*, 1–13. https://doi.org/10.1016/j.accinf.2016.06.001

Babatunde, O. K., & Low, S. P. (2013). Chinese construction firms in the Nigerian construction industry. *Habitat International*, *40*, 18–24. https://doi.org/https://doi.org/10.1016/j.habitatint.2013.01.002

Babatunde, S., Ekundayo, D., Adekunle, A., & Bello, W. (2020). Comparative analysis of drivers to BIM adoption among AEC firms in developing countries. *Journal of Engineering, Design and Technology*, *18*(6), 1425–1447. https://doi.org/10.1108/JEDT-08-2019-0217

Babatunde, S., Ekundayo, D., Babalola, O., & Jimoh, J. (2018). Analysis of the drivers and benefits of BIM incorporation into quantity surveying profession: Academia and students' perspectives. *Journal of Engineering, Design and Technology*, *16*(5), 750–766.

Babatunde, S., Perera, S., Ekundayo, D., & Adeleke, D. S. (2021). An investigation into BIM uptake among contracting firms: an empirical study in Nigeria. *Journal of Financial Management of Property and Construction*, *26*(1), 23–48. https://doi.org/10.1108/JFMPC-06-2019-0054

Babatunde, S., Udeaja, C., & Adekunle, A. (2020). Barriers to BIM implementation and ways forward to improve its adoption in the Nigerian AEC firms. *International Journal of Building Pathology and Adaptation*, *39*(1), 48–71. https://doi.org/10.1108/IJBPA-05-2019-0047

Badamasi, A. A., Aryal, K. R., Makarfi, U. U., & Dodo, M. (2021). Drivers and barriers of virtual reality adoption in UK AEC industry. *Engineering, Construction and Architectural Management*.

Baghaei Daemei, A., & Safari, H. (2018). Factors affecting creativity in the architectural education process based on computer-aided design. *Frontiers of Architectural Research*, *7*(1), 100–106. https://doi.org/https://doi.org/10.1016/j.foar.2017.09.001

Balogun, A. (2016). Infrastructure Development in Nigeria: Better late than never. In *Pwc Advisory outlook*. www.pwc.com/ng

Barbosa, F., Woetzel, J., & Mischke, J. (2017). *Reinventing Construction: A Route of Higher Productivity*. McKinsey Global Institute.

Batarseh, S., & Kamardeen, I. (2017). The Impact of Individual Beliefs and Expectations on BIM Adoption in the AEC Industry. *AUBEA 2017: Australasian Universities Build- Ing Education Association Conference*, *1*, 466–475.

Belay, S., Goedert, J., Woldesenbet, A., & Rokooei, S. (2021). Comparison of BIM Adoption Models between Public and Private Sectors through Empirical Investigation. *Advances in Civil Engineering*, *2021*, 1–13. https://doi.org/10.1155/2021/5577654

Bell, E., Bryman, A., & Harley, B. (2018). *Business Research Methods* (5th ed.). Oxford University Press.

Bensalah, M., Elouadi, A., & Mharzi, H. (2019). Overview: the opportunity of BIM in railway. *Smart and Sustainable Built Environment*, *8*(2), 103–116. https://doi.org/10.1108/SASBE-11-2017-0060

Bentler, P. M., & Bonett, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin*, *88*(3), 588.

Bertalanffy, L. von. (1969). *General system theory: Foundations, development, applications*.

Bew, M., & Richards, M. (2008). BIM maturity model. *Construct IT Autumn 2008 Members' Meeting. Brighton, UK*.

BIM Wiki. (2021). *ISO 19650*. https://www.designingbuildings.co.uk/wiki/ISO_19650

Bon-Gang, H., Xiaojing, Z., & Wei, Y. K. (2019). Effect of BIM on Rework in Construction Projects in Singapore: Status Quo, Magnitude, Impact, and Strategies. *Journal of Construction Engineering and Management*, *145*(2), 4018125. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001600

Bosurgi, G., Celauro, C., Pellegrino, O., Rustica, N., & Giuseppe, S. (2020). The BIM (Building Information Modeling)-Based Approach for Road Pavement Maintenance BT. In M. Pasetto, M. N. Partl, & G. Tebaldi (Eds.), *Proceedings of the 5th International Symposium on Asphalt Pavements & Environment (APE)* (pp. 480–490). Springer International Publishing.

BRAC. (2021). *Building Regulations Advisory Committee: golden thread repor*. https://www.gov.uk/government/publications/building-regulations-advisory-committee-golden-thread-report/building-regulations-advisory-committee-golden-thread-report

Braun, V., Clarke, V., Hayfield, N., & Terry, G. (2019). Thematic analysis. *Handbook of Research Methods in Health Social Sciences*, 843–860.

Bryman, A. (2016). *Social research methods* (5th ed.). Oxford, United Kingdom: Oxford University Press.

BSI. (2019). *Transition guidance to BS EN ISO 19650*.

Btoush, M., & Harun, A. T. (2017). Minimizing delays in the Jordanian construction industry by adopting BIM technology. *IOP Conference Series: Materials Science and Engineering*, *271*, 012041. https://doi.org/10.1088/1757-899X/271/1/012041

Bueno, C., & Fabricio, M. M. (2018). Comparative analysis between a complete LCA study and results from a BIM-LCA plug-in. *Automation in Construction*, *90*, 188–200. https://doi.org/https://doi.org/10.1016/j.autcon.2018.02.028

Bui, N., Merschbrock, C., & Munkvold, B. E. (2016). A Review of Building Information Modelling for Construction in Developing Countries. *Procedia Engineering*, *164*(1877), 487–494. https://doi.org/10.1016/j.proeng.2016.11.649

buildingSMART International. (2016). *buildingSMART Technical Vision*. http://buildingsmart.org/standards/technical-vision/

Byrne, B. M. (2013). *Structural equation modeling with Mplus: Basic concepts, applications, and programming*. Routledge.

Canziba, E. (2018). *Hands-On UX Design for Developers: Design, prototype, and implement compelling user experiences from scratch.* Packt Publishing Ltd.

Cao, D., Li, H., & Wang, G. (2014). Impacts of isomorphic pressures on BIM adoption in construction projects. *Journal of Construction Engineering and Management*, *140*(12), 4014056.

Cao, D., Li, H., Wang, G., & Huang, T. (2017). Identifying and contextualising the motivations for BIM implementation in construction projects An empirical study in China. *International Journal of Project Management*, *35*(4), 658–669. https://doi.org/10.1016/j.ijproman.2016.02.002

Cao, D., Shao, S., Huang, B., & Wang, G. (2021). Multidimensional behavioral responses to the implementation of BIM in construction projects: an empirical study in China. *Engineering, Construction and Architectural Management*. https://doi.org/10.1108/ECAM-09-2020-0735

Casasayas, O., Hosseini, M., Edwards, D., Shuchi, S., Chowdhury, M., Oskar, C., Reza, H. M., J., E. D., Sarah, S., & Mahmuda, C. (2021). Integrating BIM in Higher

Education Programs: Barriers and Remedial Solutions in Australia. *Journal of Architectural Engineering*, *27*(1), 5020010. https://doi.org/10.1061/(ASCE)AE.1943-5568.0000444

Castellano-Román, M., & Pinto-Puerto, F. (2019). Dimensions and Levels of Knowledge in Heritage Building Information Modelling, HBIM: The model of the Charterhouse of Jerez (Cádiz, Spain). *Digital Applications in Archaeology and Cultural Heritage*, *14*. https://doi.org/10.1016/j.daach.2019.e00110

Chan, D. W. M., Olawumi, T. O., & Ho, A. M. L. (2019). Perceived benefits of and barriers to Building Information Modelling (BIM) implementation in construction: The case of Hong Kong. *Journal of Building Engineering*, *25*, 100764. https://doi.org/10.1016/j.jobe.2019.100764

Charef, R., Alaka, H., & Emmitt, S. (2018). Beyond the third dimension of BIM: A systematic review of literature and assessment of professional views. *Journal of Building Engineering*, *19*, 242–257. https://doi.org/10.1016/j.jobe.2018.04.028

Chen, X. S., Liu, C. C., & Wu, I. C. (2018). A BIM-based visualization and warning system for fire rescue. *Advanced Engineering Informatics*, *37*, 42–53. https://doi.org/10.1016/j.aei.2018.04.015

Chun, M., Sohn, K., Arling, P., & Granados, N. F. (2008). Systems theory and knowledge management systems: The case of Pratt-Whitney Rocketdyne. *Proceedings of the 41st Annual Hawaii International Conference on System Sciences (HICSS 2008)*, 336.

Clough, R. H., Sears, G. A., Sears, S. K., Segner, R. O., & Rounds, J. L. (2015). *Construction contracting: A practical guide to company management*. John Wiley & Sons.

Coffey International Development Ltd. (2014). *Market Overview Report: Construction and Real Estate.*

Cohen, J. (2010). Integrated project delivery: Case studies. *AIA National, AIA California Council, AGC California and McGraw-Hill*.

Collier, J. E. (2020). *Applied structural equation modeling using AMOS: Basic to advanced techniques*. Routledge.

ConsTrack360. (2021). *Nigeria Building and Infrastructure Construction Industry*.

Costin, A., Adibfar, A., Hu, H., & Chen, S. S. (2018). Building Information Modeling (BIM) for transportation infrastructure – Literature review, applications, challenges, and recommendations. *Automation in Construction*, *94*, 257–281. https://doi.org/10.1016/j.autcon.2018.07.001

Creswell, J. W., & Clark, V. L. P. (2018). *Designing and conducting mixed methods research*. SAGE Publications Inc.

Croasmun, J. T., & Ostrom, L. (2011). Using Likert-Type Scales in the Social Sciences. *Journal of Adult Education*, *40*(1), 19–22.

Dainty, A., Leiringer, R., Fernie, S., & Harty, C. (2017). BIM and the small construction firm: a critical perspective. *Building Research and Information*, *45*(6), 696–709. https://doi.org/10.1080/09613218.2017.1293940

Dania, A. A., Larsen, G. D., & Ewart, I. J. (2014). *Sustainable construction: Exploring the capabilities of Nigerian construction firms*.

Dave, B., Buda, A., Nurminen, A., & Främling, K. (2018). A framework for integrating BIM and IoT through open standards. *Automation in Construction*, *95*, 35–45. https://doi.org/10.1016/j.autcon.2018.07.022

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(3), 319–340. https://doi.org/10.2307/249008

Davtalab, O., Kazemian, A., & Khoshnevis, B. (2018). Perspectives on a BIM-integrated software platform for robotic construction through Contour Crafting. *Automation in Construction*, *89*, 13–23. https://doi.org/https://doi.org/10.1016/j.autcon.2018.01.006

DifferenceBetween.com. (2013). *Difference Between Model and Framework*. https://www.differencebetween.com/difference-between-model-and-vs-framework/

Doan, D. T., GhaffarianHoseini, A., Naismith, N., Ghaffarianhoseini, A., Zhang, T., & Tookey, J. (2020). Examining critical perspectives on building information modelling (BIM) adoption in New Zealand. *Smart and Sustainable Built Environment*. https://doi.org/10.1108/SASBE-04-2020-0043

Doumbouya, L., Gao, G., & Guan, C. (2018). Adoption of the Building Information Modeling (BIM) for Construction Project Effectiveness: The Review of BIM Benefits. *American Journal of Civil Engineering and Architecture*, *4*(3), 74–79. http://pubs.sciepub.com/

Eadie, R., Browne, M., Odeyinka, H., Mc keown, C., & Mc niff, S. (2015). A survey of current status of and perceived changes required for BIM adoption in the UK. *Built Environment Project and Asset Management*, *5*(1), 4–21. https://doi.org/10.1108/BEPAM-07-2013-0023

Eastman, C. M. C., Eastman, C. M. C., Teicholz, P., Sacks, R., & Liston, K. (2012).

BIM Handbook: A guide to Building Information Modeling for owners, managers, designers, engineers and contractors. In *Construction Economics and Building* (2nd ed.). John Wiley & Sons. https://doi.org/10.5130/ajceb.v12i3.2749

Ebekozien, A., & Aigbavboa, C. (2021). COVID-19 recovery for the Nigerian construction sites: The role of the fourth industrial revolution technologies. *Sustainable Cities and Society*, *69*, 102803. https://doi.org/https://doi.org/10.1016/j.scs.2021.102803

Ebiloma, D., Daibi-Oruene, W., & Bumaa, F. (2017). Application of multiple regressions on the impact of building information modelling adoption drivers on sustainable construction in Nigeria. *International Journal of Innovation and Sustainability*, *1*, 22–31.

Edirisinghe, R., & London, K. (2015). Comparative analysis of international and national level BIM standardization efforts and BIM adoption. *Proceedings of the 32nd CIB W78 Conference*, 149–158.

Edirisinghe, R., London, K. A., Kalutara, P., & Aranda-Mena, G. (2017). Building information modelling for facility management: Are we there yet? *Engineering, Construction and Architectural Management*, *24*(6), 1119–1154. https://doi.org/10.1108/ECAM-06-2016-0139

Edwards, J., & Townsend, A. (2010). We're cool: Carbon reduction and built heritage can coexist. *Construction Research and Innovation*, *1*(4), 36–37. https://doi.org/10.1080/20450249.2010.11873781

Edwards, R. E., Lou, E., Bataw, A., Kamaruzzaman, S. N., & Johnson, C. (2019). Sustainability-led design: Feasibility of incorporating whole-life cycle energy assessment into BIM for refurbishment projects. *Journal of Building Engineering*, *24*, 100697. https://doi.org/10.1016/j.jobe.2019.01.027

Egan. (2002). Rethinking construction. *Structural Engineer*, *80*(14), 2. https://doi.org/Construction Task Force. Uk Government

Egwim, C. N., Alaka, H., Toriola-Coker, L. O., Balogun, H., Ajayi, S., & Oseghale, R. (2021). Extraction of underlying factors causing construction projects delay in Nigeria. *Journal of Engineering, Design and Technology*.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review*, *14*(4), 532–550.

Elangovan, N., & Rajendran, R. (2015). *Conceptual Model: A Framework for Institutionalizing the Vigor in Business Research*. https://doi.org/10.13140/RG.2.1.2164.8484

Eze, E. C., & Idiake, J. E. (2018). Impact of rework on building project and organisation performance: A view of construction professionals in Nigeria. *International Journal of Sustainable Construction Engineering and Technology*, *9*(1), 29–43.

Ezeokoli, F., Okoye, P., & Nkeleme, E. (2016). Factors Affecting the Adaptability of Building Information Modelling (BIM) for Construction Projects in Anambra State Nigeria. *Journal of Scientific Research and Reports*, *11*(5), 1–10. https://doi.org/10.9734/JSRR/2016/26563

Fadason, R. T., Danladi, C. Z., & Akut, K. L. (2018). Challenges Of Building Information Modelling Implementation In Africa A Case Of Nigerian Construction Industry. *FIG Congress 2018 Embracing Our Smart World Where the Continents Connect: Enhancing the Geospatial Maturity of Societies Istanbul, Turkey, May 6–11, 2018*, *9589*.

Fadjar Maharika, I., Irsan, A., Al Athas, S. I., Susanto, A., Abma, V., & Yuriandala, Y. (2020). Building Information Modelling (BIM) Adoption Model for Architectural Education. *Journal of Design and Built Environment*, *20*(3), 22–42. https://doi.org/10.22452/jdbe.vol20no3.2

Fagbenle, O. I., Joshua, O., Afolabi, A. O., Ojelabi, R. A., Fagbenle, O., Fagbenle, A. O., & Akomolafe, M. (2018). *Cost Management Practice of Construction Firms and Its Influencing Factors: Lessons from Southwestern Nigeria*.

Fakhimi, A., Majrouhi Sardrood, J., Mazroi, A., Ghoreishi, S. R., & Azhar, S. (2017). Influences of building information modeling (BIM) on oil, gas, and petrochemical firms. *Science and Technology for the Built Environment*, *23*(6), 1063–1077. https://doi.org/10.1080/23744731.2017.1338487

Farmer, M. (2016). Modernise or Die. *Cast Consultancy, Available at Http://Www. Cast-Consultancy. Com/Wp-Content/Uploads/2016/10/Farmer-Review-1. Pdf (Accessed 2nd August, 2018)*.

Field, A. (2018). *Discovering statistics using IBM SPSS statistics* (Fifth edit). Los Angeles : SAGE.

Fitz, D. (2020). *The overarching approach to implementing BIM in the UK*. UK BIM Framework. https://www.symetri.co.uk/insights/blog/the-overarching-approach-to-implementing-bim-in-the-uk

Folkinshteyn, D., & Lennon, M. (2016). Braving Bitcoin: A technology acceptance model (TAM) analysis. *Journal of Information Technology Case and Application Research*, *18*(4), 220–249.

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, *18*(1), 39–50.

Forrest, J. Y.-L. (2018). *General systems theory: Foundation, intuition and applications in business decision making* (Vol. 32). Springer.

Gbadamosi, A.-Q., Oyedele, L., Olawale, O., & Abioye, S. (2020). Offsite Construction for Emergencies: A focus on Isolation Space Creation (ISC) measures for the COVID-19 pandemic. *Progress in Disaster Science*, *8*, 100130. https://doi.org/https://doi.org/10.1016/j.pdisas.2020.100130

Gbadamosi, A.-Q. Q., Mahamadu, A.-M. M., Oyedele, L. O., Akinade, O. O., Manu, P., Mahdjoubi, L., & Aigbavboa, C. (2019). Offsite construction: Developing a BIM-Based optimizer for assembly. *Journal of Cleaner Production*, *215*, 1180–1190. https://doi.org/10.1016/j.jclepro.2019.01.113

General Services Administration (GSA). (2021). *3D-4D Building Information Modelin*. https://www.gsa.gov/real-estate/design-construction/3d4d-building-information-modeling

Ghafar, M. A., Ibrahim, R., Shari, Z., & Pour Rahimian, F. (2018). Integration of BIM Work Culture for Improving Global Project Collaboration Productivity. In *Contemporary Strategies and Approaches in 3-D Information Modeling* (pp. 136–157). https://doi.org/10.4018/978-1-5225-5625-1.ch006

Ghaffarianhoseini, A. A., Tookey, J., Naismith, N., Azhar, S., Efimova, O., Raahemifar, K., Ghaffarianhoseini, A. A., Naismith, N., Azhar, S., Efimova, O., & Raahemifar, K. (2017). Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges. *Renewable and Sustainable Energy Reviews*, *75*, 1046–1053. https://doi.org/https://doi.org/10.1016/j.rser.2016.11.083

Ghannad, P., Lee, Y. C., Dimyadi, J., & Solihin, W. (2019). Automated BIM data validation integrating open-standard schema with visual programming language. *Advanced Engineering Informatics*, *40*, 14–28. https://doi.org/10.1016/j.aei.2019.01.006

Gholizadeh, P., Esmaeili, B., & Goodrum, P. (2018). Diffusion of Building Information Modeling Functions in the Construction Industry. *Journal of Management in Engineering*, *34*(2), 04017060. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000589

Gimenez, L., Hippolyte, J. L., Robert, S., Suard, F., & Zreik, K. (2015). Review: Reconstruction of 3D building information models from 2D scanned plans. In

Journal of Building Engineering (Vol. 2, pp. 24–35). Elsevier. https://doi.org/10.1016/j.jobe.2015.04.002

Gledson, B. J. (2016). Hybrid project delivery processes observed in constructor BIM innovation adoption. *Construction Innovation*, *16*(2), 229–246. https://doi.org/10.1108/CI-04-2015-0020

Goepel, K. D. (2018). Implementation of an online software tool for the analytic hierarchy process (AHP-OS). *International Journal of the Analytic Hierarchy Process*, *10*(3).

Golafshani, N. (2003). Understanding Reliability and Validity in Qualitative Research. *The Qualitative Report 8:4*, *8*(4), 597–607.

Gu, N., & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction*, *19*(8), 988–999. https://doi.org/10.1016/j.autcon.2010.09.002

Hackitt, J. (2018). Building a Safer Future. *Independent Review of Building Regulations and Fire Safety: Interim Report*.

Hadi-Vencheh, A., & Niazi-Motlagh, M. (2011). An improved voting analytic hierarchy process–data envelopment analysis methodology for suppliers selection. *International Journal of Computer Integrated Manufacturing*, *24*(3), 189–197. https://doi.org/10.1080/0951192X.2011.552528

Haliburton, J. T. (2016). *Building Information Modeling and Small Architectural Practice: An Analysis of Factors Affecting BIM Adoption* [Texas A & M University]. https://hdl.handle.net/1969.1/158641

Hamada, H. M., Haron, A., Zakiria, Z., & Humada, A. M. (2017). Factor Affecting of BIM Technique in the Construction Firms in Iraq. *MATEC Web of Conferences*, *103*, 03003. https://doi.org/10.1051/matecconf/201710303003

Hamil, S. (2021). *BIM dimensions – 3D, 4D, 5D, 6D BIM explained*. NBS. https://www.thenbs.com/knowledge/bim-dimensions-3d-4d-5d-6d-bim-explained

Hamma-adama, M., & Kouider, T. (2019). Comparative analysis of BIM adoption efforts by developed countries as precedent for new adopter countries. *Current Journal of Applied Science and Technology*, *36*(2).

Hamma-adama, M., Kouider, T., & Salman, H. S. (2018). State of building information modelling (BIM) adoption in Nigeria. *Association of Researchers in Construction Management - Proceedings of the 34th Annual Conference*, 334–343.

Hamma-adama, M., Salman, H., & Kouider, T. (2018). Diffusion of Innovations: The

Status of Building Information Modelling Uptake in Nigeria. *Journal of Scientific Research and Reports*, *17*(4), 1–12. https://doi.org/10.9734/JSRR/2017/38711

Hanafi, M. H., Sing, G. G., Abdullah, S., & Ismail, R. (2016). Organisational readiness of building information modelling implementation: Architectural practices. *Jurnal Teknologi*, *78*(5), 121–126. https://doi.org/10.11113/jt.v78.8265

Hannele, K., Reijo, M., Tarja, M., Sami, P., Jenni, K., & Teija, R. (2012). Expanding uses of building information modeling in life-cycle construction projects. *Work*, *41*(Supplement 1), 114–119. https://doi.org/10.3233/WOR-2012-0144-114

Hardin, B., & McCool, D. (2015). *BIM and construction management: proven tools, methods, and workflows*. John Wiley & Sons.

Hassan, M. T., Yu, J., Zhu, W., Liu, F., Liu, J., & An, N. (2018). *Monitoring Thermal Comfort with IoT Technologies: A Pilot Study in Chinese Eldercare Centers* (pp. 303–314). https://doi.org/10.1007/978-3-319-92037-5_23

Hatem, A., Nawwar, A., & Abd Abbas, M. (2018). Motivation Factors for Adopting Building Information Modeling (BIM) in Iraq. *Engineering, Technology & Applied Science Research*, *8*(2), 2668–2672. https://doi.org/10.5281/ZENODO.1257505

Hatem, W., Abd, A., & Abbas, N. (2018). Barriers of Adoption Building Information Modeling (BIM) in Construction Projects of Iraq. *Engineering Journal*, *22*(2), 59–81. https://doi.org/10.4186/ej.2018.22.2.59

Hayduk, L. A. (1987). *Structural equation modeling with LISREL: Essentials and advances*. Jhu Press.

Herr, C. M. C. M., & Fischer, T. (2019). BIM adoption across the Chinese AEC industries: An extended BIM adoption model. *Journal of Computational Design and Engineering*, *6*(2), 173–178. https://doi.org/10.1016/j.jcde.2018.06.001

Hochscheid, E., & Halin, G. (2020). Generic and SME-specific factors that influence the BIM adoption process: an overview that highlights gaps in the literature. *Frontiers of Engineering Management*, *7*(1), 119–130.

Holzer, D. (2015). *The BIM manager's handbook, Part 2: change management*. John Wiley & Sons.

Holzer, D. (2016). *The BIM manager's handbook: guidance for professionals in architecture, engineering, and construction*. John Wiley & Sons.

Hong, Lee, Kim, & Yu. (2019). Acceptance Model for Mobile Building Information Modeling (BIM). *Applied Sciences*, *9*(18), 3668. https://doi.org/10.3390/app9183668

Hong, Y., Hammad, A. W. A., Sepasgozar, S., & Akbarnezhad, A. (2018). BIM adoption model for small and medium construction organisations in Australia. *Engineering, Construction and Architectural Management*, *26*(2), ECAM-04-2017-0064. https://doi.org/10.1108/ECAM-04-2017-0064

Hong, Y., Sepasgozar, S. M. E., Ahmadian F.F., A., & Akbarnezhad, A. (2016). Factors Influencing BIM Adoption in Small and Medium Sized Construction Organizations. *ISARC 2016 - 33rd International Symposium on Automation and Robotics in Construction*, 452–461. https://doi.org/10.22260/ISARC2016/0055

Hongping, Y., & Yu, Y. (2020). BIM Adoption under Government Subsidy: Technology Diffusion Perspective. *Journal of Construction Engineering and Management*, *146*(1), 4019089. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001733

Hosseini, M. R., Azari, E., Tivendale, L., & Chileshe, N. (2015). *Barriers to adoption of building information modeling (BIM) in Iran: Preliminary results*.

Hosseini, M. R., Banihashemi, S., Chileshe, N., Namzadi, M. O., Udaeja, C., Rameezdeen, R., & McCuen, T. (2016). BIM adoption within Australian Small and Medium-sized Enterprises (SMEs): an innovation diffusion model. *Construction Economics and Building*, *16*(3), 71–86. https://doi.org/10.5130/AJCEB.v16i3.5159

Howard, R., Restrepo, L., & Chang, C.-Y. Y. (2017). Addressing individual perceptions: An application of the unified theory of acceptance and use of technology to building information modelling. *International Journal of Project Management*, *35*(2), 107–120. https://doi.org/10.1016/j.ijproman.2016.10.012

Høyrup, S. (2010). *Employee-driven innovation and workplace learning: basic concepts, approaches and themes*. SAGE Publications Sage UK: London, England.

Ibem, E., Uwakonye, U., Akpoiroro, G., Somtochukwu, M., & Oke, C. (2018). Building information modeling (BIM) adoption in architectural firms in Lagos, Nigeria. *Int. J. Civ. Eng. Technol*, *9*, 902–915.

Ibrahim, M., Krawczyk, R., & Schipporeit, G. (2004). Two approaches to BIM: a comparative study. *ECAADe Conference*, *22*, 610–616. https://doi.org/10.1.1.68.7309

Idoro, G. I. (2012). Sustainability of mechanisation in the Nigerian construction industry. *Journal of Civil Engineering and Management*, *18*(1), 91–105.

Ikediashi, D. I., & Ogwueleka, A. C. (2016). Assessing the use of ICT systems and their impact on construction project performance in the Nigerian construction industry. *Journal of Engineering, Design and Technology*, *14*(2), 252–276. https://doi.org/10.1108/JEDT-08-2014-0047

Isibor, A. A., Ikpefan, O. A., & Okafor, T. C. (2016). Project financing: causes and effects of financing abandoned building projects in Nigeria. *The Social Sciences*, *11*(24), 5818–5823.

Ivanov, O. A., Ivanova, V. V, & Saltan, A. A. (2018). Likert-scale questionnaires as an educational tool in teaching discrete mathematics. *International Journal of Mathematical Education in Science and Technology*, *49*(7), 1110–1118.

Jacobsson, M., & Merschbrock, C. (2018). BIM coordinators: a review. *Engineering, Construction and Architectural Management*, *25*(8), 989–1008. https://doi.org/10.1108/ECAM-03-2017-0050

Jerónimo, B. M., Pieter, P., Victor, F., & Luís, M. (2016). Towards increased BIM usage for existing building interventions. *Structural Survey*, *34*(2), 168–190. https://doi.org/doi:10.1108/SS-01-2015-0002

Jong, C. Y., Sim, A. K. S., & Lew, T. Y. (2019). The relationship between TQM and project performance: Empirical evidence from Malaysian construction industry. *Cogent Business and Management*, *6*(1), 1–31. https://doi.org/10.1080/23311975.2019.1568655

Joshi, A., Kale, S., Chandel, S., & Pal, D. K. (2015). Likert scale: Explored and explained. *British Journal of Applied Science & Technology*, *7*(4), 396.

Juan, Y.-K., Lai, W.-Y., & Shih, S.-G. (2017). Building information modeling acceptance and readiness assessment in Taiwanese architectural firms. *Journal of Civil Engineering and Management*, *23*(3), 356–367. https://doi.org/10.3846/13923730.2015.1128480

Jung, W., & Lee, G. (2015). The Status of BIM Adoption on Six Continents. *International Journal of Civil, Structural, Construction and Architectural Engineering*, *9*(5), 406–410.

Kamdjoug, K., Robert, J., Harold, T. N. J., & Samuel, F. W. (2018). IT capabilities, firm performance and the mediating role of ISRM: A case study from a developing country. *Business Process Management Journal*.

Kaner, I., Sacks, R., Kassian, W., & Quitt, T. (2008). Case studies of BIM adoption for precast concrete design by mid-sized structural engineering firms. *Journal of Information Technology in Construction (ITcon)*, *13*(21), 303–323.

Kapogiannis, G., Gaterell, M., & Oulasoglou, E. (2015). Identifying uncertainties toward sustainable projects. *Procedia Engineering*, *118*, 1077–1085.

Kasimu, M. A. (2016). *Good Governance as an anti-corruption tool: Nigerian construction industry persective*.

Kassem, M., & Succar, B. (2017). Macro BIM adoption: Comparative market analysis. *Automation in Construction*, *81*, 286–299. https://doi.org/10.1016/j.autcon.2017.04.005

Khalfan, M. M. A., Anumba, C. J., Siemieniuch, C. E., & Sinclair, M. A. (2001). Readiness Assessment of the construction supply chain for concurrent engineering. *European Journal of Purchasing & Supply Management*, *7*(2), 141–153. https://www.sciencedirect.com/science/article/pii/S096970120000023X?via%3Dihub

Kheni, N. A., Dainty, A. R. J., & Gibb, A. (2008). Health and safety management in developing countries: a study of construction SMEs in Ghana. *Construction Management and Economics*, *26*(11), 1159–1169. https://www.tandfonline.com/doi/pdf/10.1080/01446190802459916?needAccess=true

Khosrowshahi, F. (2017). Building information modelling (BIM) a paradigm shift in construction. In *Building Information Modelling, Building Performance, Design and Smart Construction* (pp. 47–64). Springer International Publishing. https://doi.org/10.1007/978-3-319-50346-2_4

Khosrowshahi, F., & Arayici, Y. (2012). Roadmap for implementation of BIM in the UK construction industry. *Engineering, Construction and Architectural Management*, *19*(6), 610–635. https://doi.org/10.1108/09699981211277531

Kim, Y.-W., & Dossick, C. S. (2011). What makes the delivery of a project integrated? A case study of Children's Hospital, Bellevue, WA. *Lean Construction Journal*, 53–66.

Kline, R. B. (2011). *Convergence of structural equation modeling and multilevel modeling*. na.

Kocakaya, M. N. (2019). Building information management (BIM), a new approach to project management. *Journal of Sustainable Construction Materials and Technologies*, *4*(1), 323–332.

Kori, S., & Kiviniemi, A. (2015). *Toward adoption of BIM in the Nigerian AEC industry: context framing, data collecting and paradigm for interpretation*.

Kori, S., & Makarfi, U. (2018). Impact of employees in human capital development on bim innovation in sme firms. *International Journal of Latest Trends in Engineering* *and Technology*, *11*(3), 1–7. https://doi.org/http://dx.doi.org/10.21172/1.113.01

Kouch, A. M. (2018). A Three-Step BIM Implementation Framework for the SME Contractors. *IFIP Advances in Information and Communication Technology*, *540*, 15–24. https://doi.org/10.1007/978-3-030-01614-2_2

Kouch, A. M., Illikainen, K., & Perälä, S. (2018, July 22). Key Factors of an Initial BIM Implementation Framework for Small and Medium-sized Enterprises (SMEs). *ISARC 2018 - 35th International Symposium on Automation and Robotics in Construction and International AEC/FM Hackathon: The Future of Building Things*. https://doi.org/10.22260/ISARC2018/0126

Kouider, T., & Paterson, J. G. (2013). *Architectural technology and the BIM acronym: critical perspectives of evangelical and evolutionary paradigms for technical design.*

Kumar, A. (2019). *BIM – Ds – 2D, 3D, 4D, 5D, 6D, 7D, 8D and Benefits*. ARES Cadblogbyamit.

Kuo, R.-Z., & Lee, G.-G. (2011). Knowledge management system adoption: exploring the effects of empowering leadership, task-technology fit and compatibility. *Behaviour & Information Technology*, *30*(1), 113–129.

Lam, A. (2011). Innovative organisations: Structure, learning, and adaptation. *DIME Final Conference*, *6*, 8.

Lam, T. T., Mahdjoubi, L., & Mason, J. (2017). A framework to assist in the analysis of risks and rewards of adopting BIM for SMEs in the UK. *JOURNAL OF CIVIL ENGINEERING AND MANAGEMENT*, *23*(6), 740–752. https://doi.org/10.3846/13923730.2017.1281840

Latham, M. (1994). Constructing the Team. *HMSO London Department of the Environment*, 129. https://doi.org/978-0-11-752994-6

Lee, S., & Yu, J. (2016). Comparative Study of BIM Acceptance between Korea and the United States. *Journal of Construction Engineering and Management*, *142*(3), 05015016. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001076

Lee, S., & Yu, J. (2017). Discriminant Model of BIM Acceptance Readiness in a Construction Organization. *KSCE Journal of Civil Engineering*, *21*(3), 555–564. https://doi.org/10.1007/s12205-016-0555-9

Lee, S., Yu, J., & Jeong, D. (2015). BIM acceptance model in construction organizations. *Journal of Management in Engineering*, *31*(3), 04014048. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000252

LetsBuild. (2019). *Building Information Modeling: The future of construction*.

https://www.letsbuild.com/blog/bim-maturity-levels

Li, C. Z., Xue, F., Li, X., Hong, J., & Shen, G. Q. (2018). An Internet of Things-enabled BIM platform for on-site assembly services in prefabricated construction. *Automation in Construction*, *89*, 146–161. https://doi.org/https://doi.org/10.1016/j.autcon.2018.01.001

Li, J., Greenwood, D., & Kassem, M. (2019). Blockchain in the built environment and construction industry: A systematic review, conceptual models and practical use cases. *Automation in Construction*, *102*, 288–307. https://doi.org/10.1016/j.autcon.2019.02.005

Li, P., Zheng, S., Si, H., & Xu, K. (2019). Critical Challenges for BIM Adoption in Small and Medium-Sized Enterprises: Evidence from China. *Advances in Civil Engineering*, *2019*, 1–14. https://doi.org/10.1155/2019/9482350

Li, X., Wu, P., & Yue, T. (2019). *Integrating Building Information Modeling and Prefabrication Housing Production*. *100*(January 2018), 46–60. https://doi.org/10.1016/j.autcon.2018.12.024

Liao, L., & Ai Lin Teo, E. (2018). Organizational Change Perspective on People Management in BIM Implementation in Building Projects. *Journal of Management in Engineering*, *34*(3), 04018008. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000604

Liu, F.-H. F., & Hai, H. L. (2005). The voting analytic hierarchy process method for selecting supplier. *International Journal of Production Economics*, *97*(3), 308–317. https://doi.org/10.1016/j.ijpe.2004.09.005

Liu, H., Singh, G., Lu, M., Bouferguene, A., & Al-Hussein, M. (2018). BIM-based automated design and planning for boarding of light-frame residential buildings. *Automation in Construction*, *89*, 235–249. https://doi.org/https://doi.org/10.1016/j.autcon.2018.02.001

Liu, N., Ruan, L., Jin, R., Chen, Y., Deng, X., & Yang, T. (2019). Investigation of individual perceptions towards BIM implementation-a Chongqing case study. *Engineering, Construction and Architectural Management*, *26*(7), 1455–1475. https://doi.org/10.1108/ECAM-08-2018-0342

Liu, R., Du, J., Issa, R. R. A., & Giel, B. (2017). BIM Cloud Score: Building Information Model and Modeling Performance Benchmarking. *Journal of Construction Engineering and Management*, *143*(4), 04016109. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001251

Liu, Z., Wang, Y., Osmani, M., & Demian, P. (2020). Leveraging Micro-Level Building

Information Modeling for Managing Sustainable Design: United Kingdom Experience. *Advances in Civil Engineering*, *2020*. https://doi.org/10.1155/2020/3641950

Lu, S., & Sexton, M. (2009). *Innovation in Small Professional Practices in the Built Environment*. Oxford, UK: Blackwell Publishing Ltd. https://doi.org/10.1002/9781444316094

Ma, Z., Cai, S., Mao, N., Yang, Q., Feng, J., & Wang, P. (2018). Construction quality management based on a collaborative system using BIM and indoor positioning. *Automation in Construction*, *92*, 35–45. https://doi.org/https://doi.org/10.1016/j.autcon.2018.03.027

Machete, R., Silva, J. R., Bento, R., Falcão, A. P., Gonçalves, A. B., Lobo de Carvalho, J. M., & Silva, D. V. (2021). Information transfer between two heritage BIMs for reconstruction support and facility management: the case study of the Chalet of the Countess of Edla, Sintra, Portugal. *Journal of Cultural Heritage*. https://doi.org/10.1016/j.culher.2021.02.010

Makabate, C. T., Musonda, I., Okoro, C. S., & Chileshe, N. (2021). Scientometric analysis of BIM adoption by SMEs in the architecture, construction and engineering sector. *Engineering, Construction and Architectural Management*. https://doi.org/10.1108/ECAM-02-2020-0139

Makarfi, U. (2022). Beyond developing framework(s) within the construction and built environment: using UX/UI design concepts to develop and validate a digital prototype application. *IPGRC 2022: Resilience in Research and Practice*. https://hub.salford.ac.uk/ipgrc-conference-2022/

Makarfi, U., & Kori, S. (2018). The role of internal relationship capital in motivating bim innovation in sme firms. *International Journal of Latest Trends in Engineering and Technology*, *11*(3), 1–8. https://doi.org/http://dx.doi.org/10.21172/1.113.02

Makarfi, U., & Udeaja, C. (2018). A theoretical model for innovation adoption within SME. *Lean Construction Institute (LCI-UK) Summit, Birmingham UK*.

Makarfi, U., & Udeaja, C. (2019). To formulate a conceptual model for innovation: Reframing theoretical constructs of bim adoption within sme organisations. *Association of Researchers in Construction Management, ARCOM 2019 - Proceedings of the 35th Annual Conference*, 265–272.

Makarfi, U., & Underwood, J. (2021). Developing an Interactive Digital Framework for BIM Adoption: The Nigerian Small Medium Architectural Firms. *Salford Postgraduate Annual Researcher Conference (SPARC), MediaCity UK.*

Manu, P., Poghosyan, A., Mahamadu, A.-M., Mahdjoubi, L., Gibb, A., Behm, M., & Akinade, O. O. (2019). Design for occupational safety and health: key attributes for organisational capability. *Engineering, Construction and Architectural Management*.

Manzoor, B., Othman, I., Gardezi, S. S. S., Altan, H., & Abdalla, S. B. (2021). BIM-Based Research Framework for Sustainable Building Projects: A Strategy for Mitigating BIM Implementation Barriers. *Applied Sciences*, *11*(12), 5397. https://doi.org/10.3390/app11125397

Manzoor, B., Othman, I., Shujaa, S., Gardezi, S., & Harirchian, E. (2021). *buildings Strategies for Adopting Building Information Modeling (BIM) in Sustainable Building Projects-A Case of Malaysia*. https://doi.org/10.3390/buildings11060249

MarketsandMarkets. (2020). *Building Information Modeling Market*. https://www.marketsandmarkets.com/Market-Reports/building-information-modeling-market-95037387.html

Marsal-Llacuna, M.-L. (2018). Future living framework: Is blockchain the next enabling network? *Technological Forecasting and Social Change*, *128*, 226–234. https://doi.org/https://doi.org/10.1016/j.techfore.2017.12.005

Martin, P., Beladjine, D., & Beddiar, K. (2019). Evolution within the maturity concept of BIM. *WIT Transactions on The Built Environment*, *192*, 131–142.

Martínez-Aires, M. D., López-Alonso, M., & Martínez-Rojas, M. (2018). Building information modeling and safety management: A systematic review. *Safety Science*, *101*, 11–18. https://doi.org/10.1016/j.ssci.2017.08.015

Maskil-Leitan, R., & Reychav, I. (2018). A sustainable sociocultural combination of building information modeling with integrated project delivery in a social network perspective. *Clean Technologies and Environmental Policy*, *20*(5), 1017–1032. https://doi.org/10.1007/s10098-018-1526-2

Matarneh, R., & Hamed, S. (2017). Barriers to the Adoption of Building Information Modeling in the Jordanian Building Industry. In *Open Journal of Civil Engineering* (Vol. 07, Issue 03). https://doi.org/10.4236/ojce.2017.73022

Building information modeling for facilities management: A literature review and future research directions, 24 Journal of Building Engineering 100755 (2019). https://doi.org/10.1016/j.jobe.2019.100755

May, E. M., Hunter, B. A., & Jason, L. A. (2017). Methodological pluralism and mixed methodology to strengthen community psychology research: an example from oxford house. *Journal of Community Psychology*, *45*(1), 100–116. https://doi.org/10.1002/jcop.21838

McGuirk, H., Lenihan, H., & Hart, M. (2015). Measuring the impact of innovative human capital on small firms' propensity to innovate. *Research Policy*, *44*(4), 965–976.

Meex, E., Hollberg, A., Knapen, E., Hildebrand, L., & Verbeeck, G. (2018). Requirements for applying LCA-based environmental impact assessment tools in the early stages of building design. *Building and Environment*, *133*, 228–236. https://doi.org/https://doi.org/10.1016/j.buildenv.2018.02.016

Merschbrock, C., & Munkvold, B. E. (2015). Effective digital collaboration in the construction industry–A case study of BIM deployment in a hospital construction project. *Computers in Industry*, *73*, 1–7.

Milford, R. (2012). Institution building in construction industries in developing countries. In *New perspectives on construction in developing countries* (pp. 129–152). Routledge.

Mohammad, W., Abdullah, M., & Ismail, S. (2018). *Understanding the Concept of Building Information Modeling: A Literature Review*. http://hrmars.com/hrmars_papers/Understanding_the_Concept_of_Building_Information_Modeling_A_Literature_Review.pdf

Mohammad, W. N. S., Abdullah, M. R., Ismail, S., & Takim, R. (2019). Technology-Organisation-Environment Framework for Building Information Modelling (BIM) Adoption Challenges for Contractor's Organisations in Malaysia. *Journal of Computational and Theoretical Nanoscience*, *16*(5), 2282–2288. https://doi.org/10.1166/jctn.2019.7885

Mohd Sabri, N. S., Bidin, Z. A., & Mohammad Bohari, A. A. (2018). Integrated data management: Building Information Modeling (BIM) in Malaysia construction industry. *ACM International Conference Proceeding Series*, 139–142. https://doi.org/10.1145/3185089.3185141

Moledina, M. M. G., Pin, G. W., Enegbuma, W. I., Ali, K. N., & Adenuga, K. (2017). Building information modelling technological innovations in industrialised building systems cost estimation. *2017 International Conference on Research and Innovation in Information Systems (ICRIIS)*, 1–6. https://doi.org/10.1109/ICRIIS.2017.8002480

Monozam, N. H., Monazam, H. H., Hosseini, M. R., & Zaeri, F. (2016). Barriers to adopting building information modelling (BIM) within south Australian small and medium sized enterprises. *Project Management Development - Practice &*

Perspectives, 125–132. http://search.ebscohost.com/login.aspx?direct=true&AuthType=shib,cookie,ip,url,uid&db=buh&AN=114835252&custid=s2888710

Mueller, R. O., & Hancock, G. R. (2018). Structural equation modeling. In *The reviewer's guide to quantitative methods in the social sciences* (pp. 445–456). Routledge.

Mulder, P. (2017). *Conceptual Framework*. toolshero: https://www.toolshero.com/problem-solving/conceptual-framework/

Murguia, D., Demian, P., & Soetanto, R. (2021). Systemic BIM Adoption: A Multilevel Perspective. *Journal of Construction Engineering and Management*, *147*(4), 04021014. https://doi.org/10.1061/(ASCE)CO.1943-7862.0002017

Mustaffa, N. E., Salleh, R. M., & Ariffin, H. L. B. T. (2017). Experiences of Building Information Modelling (BIM) adoption in various countries. *2017 International Conference on Research and Innovation in Information Systems (ICRIIS)*, 1–7. https://doi.org/10.1109/ICRIIS.2017.8002508

Napaporn, K., & Arthur, T. (2009). The Role of a Modified Technology acceptance Model in Explaining Internet usage in Higher Education in Thailand. *International Journal*, *1*(June), 1–3. https://doi.org/10.4018/jantti.2009040103

National Bureau of Statistics. (2021). *Nigerian Gross Domestic Product Report*.

Nations, U. (2018). *2018 revision of world urbanization prospects*. United Nations Department of Economic and Social Affairs.

NBS. (2020). *10th Annual BIM Report*.

Neely, A. (2018). Carrying the Torch for Digital Built Britain. In *BIMPlus*.

Newswire, P. R. (2018). *Global Construction Outlook 2022*.

Nonaka, I., & Toyama, R. (2015). The knowledge-creating theory revisited: knowledge creation as a synthesizing process. In *The essentials of knowledge management* (pp. 95–110). Springer.

North, K., Aramburu, N., & Lorenzo, O. J. (2020). Promoting digitally enabled growth in SMEs: a framework proposal. *Journal of Enterprise Information Management*, *33*(1), 238–262. https://doi.org/10.1108/JEIM-04-2019-0103

O'Neill, M. J. (2010). A model of environmental control and effective work. *Facilities*, *28*(3/4), 118–136. https://doi.org/10.1108/02632771011023104

Obianyo, I. I., Ihekweme, G. O., Mahamat, A. A., Onyelowe, K. C., Onwualu, A. P., & Soboyejo, A. B. O. (2021). Overcoming the obstacles to sustainable housing and urban development in Nigeria: The role of research and innovation. *Cleaner Engineering and Technology*, *4*, 100226. https://doi.org/https://doi.org/10.1016/j.clet.2021.100226

Ogundipe, K. E., Olaniran, H. F., Ajao, A. M., & Ogunbayo, B. F. (2018). ASSESSING THE IMPACT OF QUALITY SUPERVISION ON CONSTRUCTION OPERATIVES'PROJECT DELIVERY IN NIGERIA. *International Journal of Civil Engineering and Technology*, *9*(9), 426–439.

Ogunnusi, M., Omotayo, T., Hamma-Adama, M., Awuzie, B. O., & Egbelakin, T. (2021). Lessons learned from the impact of COVID-19 on the global construction industry. *Journal of Engineering, Design and Technology*, *ahead-of-p*(ahead-of-print). https://doi.org/10.1108/JEDT-05-2021-0286

Ojelabi, R. A., Omuh, I. O., Afolabi, A. O., & Tunji-Olayeni, P. F. (2019). Assessment of building information modeling uptake in the management of construction projects. *10th International Structural Engineering and Construction Conference, ISEC 2019*.

Oke, A. E., & Ugoje, O. F. (2013). Assessment of rework cost of selected building projects in Nigeria. *International Journal of Quality & Reliability Management*.

Okolie, K., Ezeokoli, F., & Fadumo, D. (2020). Positioning the Nigerian Construction Industry and Desiderata for Global Competitiveness in the 21st Century. *Journal of Engineering Research and Reports*, 20–31.

Olanrewaju, O., Babarinde, S., Chileshe, N., & Sandanayake, M. (2021). Drivers for implementation of building information modeling (BIM) within the Nigerian construction industry. *Journal of Financial Management of Property and Construction*, *ahead-of-p*(ahead-of-print). https://doi.org/10.1108/JFMPC-12-2019-0090

Olanrewaju, O., Chileshe, N., Babarinde, S., & Sandanayake, M. (2020). Investigating the barriers to building information modeling (BIM) implementation within the Nigerian construction industry. *Engineering, Construction and Architectural Management*, *27*(10), 2931–2958. https://doi.org/10.1108/ECAM-01-2020-0042

Olanrewaju, O., Kineber, A., Chileshe, N., & Edwards, D. (2021). *Modelling the Impact of Building Information Modelling (BIM) Implementation Drivers and Awareness on Project Lifecycle*. https://doi.org/10.3390/su13168887

Olawumi, T. O., & Chan, D. W. M. (2020). Green-building information modelling (Green-BIM) assessment framework for evaluating sustainability performance of building projects: a case of Nigeria. *Architectural Engineering and Design Management*, 1–20. https://doi.org/10.1080/17452007.2020.1852910

Olawumi, T. O., Chan, D. W. M., Wong, J. K. W., & Chan, A. P. C. (2018). Barriers to the integration of BIM and sustainability practices in construction projects: A Delphi survey of international experts. *Journal of Building Engineering*, *20*, 60–71. https://doi.org/10.1016/j.jobe.2018.06.017

Oliveira, T., & Martins, M. F. (2011). Literature review of information technology adoption models at firm level. *Electronic Journal of Information Systems Evaluation*, *14*(1), 110.

Oloke, O. C., Oni, A. S., Ogunde, A., Opeyemi, J., & Babalola, D. O. (2017). Incessant building collapse in Nigeria: a framework for post-development management control. *Developing Country Studies*, *7*(3), 114–127.

Olusegun, A. E., Benson, O. A., Esther, A. I., & Michael, A. O. (2011). Corruption in the construction industry of Nigeria: causes and solutions. *Journal of Emerging Trends in Economics and Management Sciences (JETEMS)*, *2*(3), 156–159.

Oluwatayo, Adedapo Adewumi. (2009). *A critical study of the practice characteristics of architectural firms in Nigeria*. Covenant University.

Oluwatayo, Adedapo Adewunmi, & Amole, D. (2013). Ownership, structure, and performance of architectural firms. *Frontiers of Architectural Research*, *2*(1), 94–106.

Omede, V., & Saidu, I. (2020). Factors influencing buildong material price fluctuation in Abuja, Nigeria. *SECTIC 2020 International Conference: Sustainable Housing and Land Management*.

Omitogun, O., Longe, A. E., & Muhammad, S. (2018). The impact of oil price and revenue variations on economic growth in Nigeria. *OPEC Energy Review*, *42*(4), 387–402.

Onososen, A., & Adeyemo, M. (2020). BIM Practice: Training and Education of Nigerian Quantity Surveyors in Preparation for BIM Adoption. *PM World*, *9*(2). www.pmworldjournal.com

Onungwa, I. O., & Uduma-Olugu, N. (2017). Building information modelling and collaboration in the Nigerian construction industry. *Journal of Construction Business and Management*, *1*(2), 1–10.

Onungwa, I., Uduma-Olugu, N., & Igwe, J. (2017). Building information modelling as a construction management tool in Nigeria. *WIT Transactions on the Built Environment*, *169*, 25–33. https://doi.org/10.2495/BIM170031

Oraee, M., Hosseini, M. R., Edwards, D., & Papadonikolaki, E. (2021). Collaboration in BIM-based construction networks: a qualitative model of influential factors.

Engineering, Construction and Architectural Management. https://doi.org/10.1108/ECAM-10-2020-0865

Oramah, I. T. (2016). The effects of population growth in Nigeria. *Journal of Applied Sciences*, *6*(6), 1332–1337.

Osuizugbo, I. C. (2021). Disruptions and Responses within Nigeria Construction Industry amid COVID-19 Threat. *Covenant Journal of Research in the Built Environment*, *8*(2).

Oyedele, L. O., Jaiyeoba, B. E., Kadiri, K. O., Folagbade, S. O., Tijani, I. K., & Salami, R. O. (2015). Critical factors affecting construction quality in Nigeria: evidence from industry professionals. *International Journal of Sustainable Building Technology and Urban Development*, *6*(2), 103–113.

Oyewobi, L. O., & Ogunsemi, D. R. (2010). Factors influencing reworks occurrence in construction: A study of selected building projects in Nigeria. *Journal of Building Performance*, *1*(1).

Oyewole, E. O., & Dada, J. O. (2019). Training gaps in the adoption of building information modelling by Nigerian construction professionals. *Built Environment Project and Asset Management*.

Pallant, J. (2016). *SPSS survival manual* (6th ed.). McGraw-hill Education (UK).

Panuwatwanich, K., & Peansupap, V. (2013). Factors affecting the current diffusion of BIM: a qualitative study of online professional network. *Creative Construction Conference, Budapest, Hungary*, 6–9.

Papadonikolaki, E, & Aibinu, A. (2017). The influence of leadership, resources and organisational structure on BIM adoption. *Proceedings of the 33rd Annual ARCOM Conference*, *33*(2017), 12.

Papadonikolaki, Eleni. (2016). Alignment of Partnering with Construction IT: Exploration and Synthesis of network strategies to integrate BIM-enabled Supply Chains. In *A+BE Architecture and the Built Environment* (Vol. 20, pp. 1–328). https://doi.org/10.16057/j.cnki.31-1171/g2.2016.04.003

Papadonikolaki, Eleni. (2018). Loosely Coupled Systems of Innovation: Aligning BIM Adoption with Implementation in Dutch Construction. *Journal of Management in Engineering*, *34*(6), 05018009. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000644

Piroozfar, P., Farr, E. R. P., Zadeh, A. H. M., Timoteo Inacio, S., Kilgallon, S., & Jin, R. (2019). Facilitating Building Information Modelling (BIM) using Integrated Project Delivery (IPD): A UK perspective. *Journal of Building Engineering*, *26*, 100907.

https://doi.org/10.1016/j.jobe.2019.100907

Plageras, A. P., Psannis, K. E., Stergiou, C., Wang, H., & Gupta, B. B. (2018). Efficient IoT-based sensor BIG Data collection–processing and analysis in smart buildings. *Future Generation Computer Systems*, *82*, 349–357. https://doi.org/https://doi.org/10.1016/j.future.2017.09.082

Poirier, E. A., Forgues, D., & Staub-French, S. (2017). Understanding the impact of BIM on collaboration: a Canadian case study. *Building Research and Information*, *45*(6), 681–695. https://doi.org/10.1080/09613218.2017.1324724

Poirier, E., Staub-French, S., & Forgues, D. (2015). Embedded contexts of innovation: BIM adoption and implementation for a specialty contracting SME. *Construction Innovation*, *15*(1), 42–65. https://doi.org/10.1108/CI-01-2014-0013

Prabhakaran, A., Mahamadu, A.-M., Mahdjoubi, L., Andric, J., Manu, P., & Mzyece, D. (2021). An investigation into macro BIM maturity and its impacts: a comparison of Qatar and the United Kingdom. *Architectural Engineering and Design Management*, 1–20. https://doi.org/10.1080/17452007.2021.1923454

Qin, X., Shi, Y., Lyu, K., & Mo, Y. (2020). USING A TAM-TOE MODEL TO EXPLORE FACTORS OF BUILDING INFORMATION MODELLING (BIM) ADOPTION IN THE CONSTRUCTION INDUSTRY. *JOURNAL OF CIVIL ENGINEERING AND MANAGEMENT*, *26*(3), 259–277. https://doi.org/10.3846/jcem.2020.12176

Rahman, R. A., Alsafouri, S., Tang, P., & Ayer, S. K. (2016). Comparing Building Information Modeling Skills of Project Managers and BIM Managers Based on Social Media Analysis. *Procedia Engineering*, *145*, 812–819. https://doi.org/10.1016/j.proeng.2016.04.106

Reizgevičius, M., Ustinovičius, L., Cibulskienė, D., Kutut, V., & Nazarko, L. (2018). Promoting sustainability through investment in Building Information Modeling (BIM) technologies: A design company perspective. *Sustainability (Switzerland)*, *10*(3), 600. https://doi.org/10.3390/su10030600

Reza Hosseini, M., Pärn, E. A. A., Edwards, D. J. J., Papadonikolaki, E., & Oraee, M. (2018). Roadmap to Mature BIM Use in Australian SMEs: Competitive Dynamics Perspective. *Journal of Management in Engineering*, *34*(5), 05018008. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000636

Rogers, E M. (2003). *Diffusion of Innovations, 5th Edition*. Free Press. https://books.google.co.uk/books?id=9U1K5LjUOwEC

Rogers, Everett M. (1995). Diffusion of Innovations: Modifications of a Model for Telecommunications. In *Die Diffusion von Innovationen in der*

Telekommunikation (pp. 25–38). Springer. https://doi.org/10.1007/978-3-642-79868-9_2

Rowlinson, S. (2017). Building information modelling, integrated project delivery and all that. *Construction Innovation*, *17*(1), 45–49. https://doi.org/10.1108/CI-05-2016-0025

Saaty, R. W. (1987). The analytic hierarchy process-what it is and how it is used. *Mathematical Modelling*, *9*(3–5), 161–176. https://doi.org/10.1016/0270-0255(87)90473-8

Sabri, N. S. M., Bidin, Z. A., & Bohari, A. A. M. (2018). Integrated Data Management. *Proceedings of the 2018 7th International Conference on Software and Computer Applications - ICSCA 2018*, 139–142. https://doi.org/10.1145/3185089.3185141

Sacks, R., Eastman, C., Lee, G., & Teicholz, P. (2018). *BIM handbook: A guide to building information modeling for owners, designers, engineers, contractors, and facility managers*. John Wiley & Sons.

Sacks, R., Kedar, A., Borrmann, A., Ma, L., Brilakis, I., Hüthwohl, P., Daum, S., Kattel, U., Yosef, R., Liebich, T., Barutcu, B. E., Muhic, S., Brilakise, I., Hüthwohle, P., Daumc, S., Kattela, U., Yosefa, R., Liebichf, T., Barutcuf, B. E., & Muhic, S. (2018). SeeBridge as next generation bridge inspection: Overview, Information Delivery Manual and Model View Definition. *Automation in Construction*, *90*, 134–145. https://doi.org/https://doi.org/10.1016/j.autcon.2018.02.033

Saidu, I., & Shakantu, W. (2017a). A post-contract project analysis of material waste and cost overrun on construction sites in Abuja, Nigeria. *Acta Structilia*, *24*(2), 77–105.

Saidu, I., & Shakantu, W. (2017b). An investigation into cost overruns for ongoing building projects in Abuja, Nigeria. *Acta Structilia*, *24*(1), 53–72.

Saka, A., & Chan, D. (2019a). A Global Taxonomic Review and Analysis of the Development of BIM Research between 2006 and 2017. *Construction Innovation*.

Saka, A., & Chan, D. (2019b). A Scientometric review and Metasynthesis of building information modelling (BIM) research in Africa. *Buildings*, *9*(4), 85. https://doi.org/10.3390/buildings9040085

Saka, A., & Chan, D. (2019c). A Scientometric review and Metasynthesis of building information modelling (BIM) research in Africa. *Buildings*, *9*(4), 85.

Saka, A., & Chan, D. (2020). Profound barriers to building information modelling (BIM) adoption in construction small and medium-sized enterprises (SMEs). *Construction Innovation*, *20*(2), 261–284. https://doi.org/10.1108/CI-09-2019-

0087

Saka, A., & Chan, D. (2021). Adoption and implementation of building information modelling (BIM) in small and medium-sized enterprises (SMEs): a review and conceptualization. *Engineering, Construction and Architectural Management*, *28*(7), 1829–1862. https://doi.org/10.1108/ECAM-06-2019-0332

Saka, A., Chan, D., & Siu, F. (2020). Drivers of Sustainable Adoption of Building Information Modelling (BIM) in the Nigerian Construction Small and Medium-Sized Enterprises (SMEs). *Sustainability*, *12*(9), 3710. https://doi.org/10.3390/su12093710

Sanchís-Pedregosa, C., Vizcarra-Aparicio, J.-M., & Leal-Rodríguez, A. L. (2020). BIM: a technology acceptance model in Peru. *Journal of Information Technology in Construction*, *25*, 99–108. https://doi.org/10.36680/j.itcon.2020.006

Sardroud, J. M., Mehdizadehtavasani, M., Khorramabadi, A., & Ranjbardar, A. (2018). Barriers analysis to effective implementation of BIM in the construction industry. *ISARC 2018 - 35th International Symposium on Automation and Robotics in Construction and International AEC/FM Hackathon: The Future of Building Things*.

Saunders, M. N. K., Lewis, P., & Thornhill, A. (2019). *Research methods for business students* (Eighth). New York : Pearson.

Schindler, P. S., & Cooper, D. R. (2006). *Marketing research*. Tata McGraw-Hill Education.

Selçuk Çıdık, M., Boyd, D., & Thurairajah, N. (2017). Innovative Capability of Building Information Modeling in Construction Design. *Journal of Construction Engineering and Management*, *143*(8), 04017047. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001337

Semaan, J., Underwood, J., & Hyde, J. (2021). An investigation of work-based education and training needs for effective BIM adoption and implementation: an organisational upskilling model. *Applied Sciences*, *11*(18), 8646.

Shepherd, D. (2019). *The BIM Management Handbook*. Routledge.

Sher, W., Olatunji, O. a., & Ogunsemi, D. R. (2010). The impact of Building Information Modelling on Construction Cost estimation. *W055-Special Track 18th CIB World Building Congress May 2010 Salford, United Kingdom*, *2308*, 193.

Simon, S. E. (1944). *The placing and management of building contracts: report of the Central Council for Works and Buildings*. HM Stationery Office.

Smith, N. J. (2002). *Engineering project management*. Blackwell Science Ames, IA.

Smits, W., van Buiten, M., & Hartmann, T. (2017). Yield-to-BIM: impacts of BIM maturity on project performance. *Building Research and Information*, *45*(3), 336–346. https://doi.org/10.1080/09613218.2016.1190579

Son, H., Lee, S., & Kim, C. (2015). What drives the adoption of building information modeling in design organizations? An empirical investigation of the antecedents affecting architects' behavioral intentions. *Automation in Construction*, *49*(PA), 92–99. https://doi.org/10.1016/J.AUTCON.2014.10.012

Sönmez, N. O. (2018). A review of the use of examples for automating architectural design tasks. *Computer-Aided Design*, *96*, 13–30. https://doi.org/https://doi.org/10.1016/j.cad.2017.10.005

Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. *Automation in Construction*, *18*(3), 357–375. https://ac.els-cdn.com/S0926580508001568/1-s2.0-S0926580508001568-main.pdf?_tid=2bda1b9b-20b8-454e-9421-19caeda1de82&acdnat=1529494836_3731ccba82efec6a35edcf3d76892fb7

Succar, B., & Kassem, M. (2015). Macro-BIM adoption: Conceptual structures. *Automation in Construction*, *57*, 64–79. https://doi.org/10.1016/j.autcon.2015.04.018

Succar, B., Sher, W., & Williams, A. (2012). Measuring BIM performance: Five metrics. *Architectural Engineering and Design Management*, *8*(2), 120–142.

Succar, B., Sher, W., & Williams, A. (2013). An integrated approach to BIM competency assessment, acquisition and application. *Automation in Construction*, *35*, 174–189. https://doi.org/10.1016/j.autcon.2013.05.016

Tan, T., Chen, K., Xue, F., & Lu, W. (2019). Barriers to Building Information Modeling (BIM) implementation in China's prefabricated construction: An interpretive structural modeling (ISM) approach. *Journal of Cleaner Production*, *219*, 949–959. https://doi.org/10.1016/j.jclepro.2019.02.141

Tang, S., Shelden, D. R., Eastman, C. M., Pishdad-Bozorgi, P., & Gao, X. (2019). A review of building information modeling (BIM) and the internet of things (IoT) devices integration: Present status and future trends. *Automation in Construction*, *101*, 127–139. https://www.sciencedirect.com/science/article/pii/S0926580518305764

Tang, X., Chong, H.-Y., & Zhang, W. (2019). Relationship between BIM implementation and performance of OSM projects. *Journal of Management in*

Engineering, *35*(5), 4019019.

Tanko, B. L., Abdullah, F., & Ramly, Z. M. (2017). Stakeholders assessment of constraints to project delivery in the Nigerian construction industry. *International Journal of Built Environment and Sustainability*, *4*(1).

Toole, T. M. (1998). Uncertainty and home builders' adoption of technological innovations. *Journal of Construction Engineering and Management*, *124*(4), 323–332.

Tsai, C.-F., & Yen, Y.-F. (2020). Moderating effect of employee perception of responsible downsizing on job satisfaction and innovation commitment. *The International Journal of Human Resource Management*, *31*(15), 1913–1937. https://doi.org/10.1080/09585192.2018.1424014

Tulke, J., & Schumann, R. (2018). BIM Manager. In *Building Information Modeling* (pp. 293–302). Springer.

Ugochukwu, S., Akabogu, S., & Okolie, K. (2015). Status and Perceptions of the Application of Building Information Modeling for Improved Building Projects Delivery in Nigeria. *American Journal of Engineering Research (AJER)*, *4*(11), 176–182.

Uhm, M., Lee, G., & Jeon, B. (2017). An analysis of BIM jobs and competencies based on the use of terms in the industry. *Automation in Construction*, *81*(June), 67–98. https://doi.org/10.1016/j.autcon.2017.06.002

UK BIM Alliance. (2021). *State of the Nation Survey 2021*.

UKBIM Framework. (2021). Information Management According to BS EN ISO 19650 Guidance Part A: The information management function and resources. In *UK BIM Alliance,(July)*.

Underwood, J., Ayoade, O. A., Khosrowshahi, F., Greenwood, D., Pittard, S., & Garvey, R. (2015). *Current position and associated challenges of BIM education in UK higher education*.

Underwood, J., & Isikdag, U. (2011). Emerging technologies for BIM 2.0. *Construction Innovation*, *11*(3), 252–258. https://doi.org/10.1108/14714171111148990

Underwood, J., Shelbourn, M., Carlton, D., Zhao, G., Simpson, M., Aksenova, G., & Mollasalehi, S. (2021). Transforming the Productivity of People in the Built Environment: Emergence of a Digital Competency Management Ecosystem. In *Handbook of Research on Driving Transformational Change in the Digital Built Environment* (pp. 430–466). IGI Global.

Usman, N., Abubakar, M., & Ibrahim, M. (2016). Assessment of Some Key Issues that

Affect the Acceptance of Building Information Modelling (BIM). *ATBU Journal of Environmental Technology*, *9*(2), 40–52.

V Doraisamy, S., Akasha, Z. A., & Yunus, R. (2015). A review on abandoned construction projects: Causes & effects. *Applied Mechanics and Materials*, *773*, 979–983.

van Oorschot, J. A. W. H., Hofman, E., & Halman, J. I. M. (2018). A bibliometric review of the innovation adoption literature. *Technological Forecasting and Social Change*, *134*, 1–21. https://doi.org/10.1016/J.TECHFORE.2018.04.032

Walasek, D., & Barszcz, A. (2017). Analysis of the Adoption Rate of Building Information Modeling [BIM] and its Return on Investment [ROI]. *Procedia Engineering*, *172*, 1227–1234. https://doi.org/https://doi.org/10.1016/j.proeng.2017.02.144

Wang, C. (2015). Assessment of BIM implementation among MEP firms in Nigeria. *International Journal of Advances in Applied Sciences*, *4*(3), 73–81.

Wang, G., & Song, J. (2017). The relation of perceived benefits and organizational supports to user satisfaction with building information model (BIM). *Computers in Human Behavior*, *68*, 493–500. https://doi.org/10.1016/j.chb.2016.12.002

Wang, Jichuan, & Wang, X. (2019). *Structural equation modeling: Applications using Mplus*. John Wiley & Sons.

Wang, Jing, & Lu, W. (2021). A deployment framework for BIM localization. *Engineering, Construction and Architectural Management*, *ahead-of-p*(ahead-of-print). https://doi.org/10.1108/ECAM-09-2020-0747

Wang, Y., Thangasamy, V. K., Hou, Z., Tiong, R. L. K., & Zhang, L. (2020). Collaborative relationship discovery in BIM project delivery: A social network analysis approach. *Automation in Construction*, *114*, 103147. https://doi.org/https://doi.org/10.1016/j.autcon.2020.103147

Winfield, M., & Rock, S. (2018). The winfield rock report: Overcoming the legal and contractual barriers of BIM. In *Winfield Rock Report Overcoming the Legal and Contractual Barriers BIM*. https://www.ukbimalliance.org/winfield-rock-report-2/

Wong, A. K. D., Wong, F. K. W., Nadeem, A., Wong, A. K. D., Wong, F. K. W., Attributes, A. N., Wong, A. K. D., Wong, F. K. W., & Nadeem, A. (2015). Attributes of Building Information Modelling Implementations in Various Countries Attributes of Building Information Modelling Implementations in Various Countries. *Architectural Engineering and Design Management*, *2007*(November), 288–303. https://doi.org/10.3763/aedm.2010.IDDS6

World Bank. (2016). *From Oil to Cities: Nigeria's Next Transformation*. The World Bank.

World Bank. (2021). *Demographic trends and urbanization*. https://doi.org/978-1-4648-1112-9

Yilmaz, G., Akcamete, A., & Demirors, O. (2019). A reference model for BIM capability assessments. *Automation in Construction*, *101*, 245–263. https://doi.org/10.1016/j.autcon.2018.10.022

Yin, R. K. (2018). *Case Study Research and Applications: Design and Methods* (6th ed.). Los Angeles : SAGE.

Ying, H., Ahmed, H., Xiaoyang, Z., Beibei, W., & Ali, A. (2020). Comparative Modeling Approach to Capture the Differences in BIM Adoption Decision-Making Process in Australia and China. *Journal of Construction Engineering and Management*, *146*(2), 4019099. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001746

Zhang, C., Nizam, R. S., & Tian, L. (2018). BIM-based investigation of total energy consumption in delivering building products. *Advanced Engineering Informatics*, *38*, 370–380. https://doi.org/10.1016/j.aei.2018.08.009

Zhao, D., McCoy, A. P., Bulbul, T., Fiori, C., & Nikkhoo, P. (2015). Building collaborative construction skills through BIM-integrated learning environment. *International Journal of Construction Education and Research*, *11*(2), 97–120.

Zheng, X., Lu, Y., Li, Y., Le, Y., & Xiao, J. (2019). Quantifying and visualizing value exchanges in building information modeling (BIM) projects. *Automation in Construction*, *99*, 91–108. https://doi.org/10.1016/j.autcon.2018.12.001

Appendix

Appendix 1: Ethical Approval Letter

University of Salford
MANCHESTER

Research, Innovation and Academic Engagement Ethical Approval Panel

Doctoral & Research Support
Research and Knowledge Exchange,
Room 827, Maxwell Building
University of Salford
Manchester
M5 4WT

T +44(0)161 295 5278

www.salford.ac.uk/

29 October 2018

Usman Makarfi

Dear Usman,

RE: ETHICS APPLICATION STR1819-05: Developing an organizational Acceptance Model of BIM usage within Small Medium Enterprises.

Based on the information you provided, I am pleased to inform you that your application STR1819-05 has been approved.

If there are any changes to the project and/ or its methodology, please inform the Panel as soon as possible by contacting S&T-ResearchEthics@salford.ac.uk

Yours sincerely,

APHigham.

Dr Anthony Higham
Chair of the Science & Technology Research Ethics Panel

Appendix 2: Definitions of BIM

Author	Year	Definition
Jung and Gibson	1999	"Integration of corporate strategy, management, computer systems, and information technology throughout the project's entire lifecycle and across different business functions."
Graphisoft	2003	"A computer model database of building design information, which may also contain information about a building's construction, management, operations and maintenance."
Penttila	2006	"A methodology to manage the essential building design and project data in digital format throughout the building life cycle."
National Institute of Building Sciences	2007	"A digital representation of the geometric and non-geometric data of a facility."
AIA	2008	"A digital representation of the physical and functional characteristics of the single model or multiple models' elements, and the process and technology used to create the model."
Autodesk	2008	"An innovative approach to building design, construction, and management that is characterized by the continuous and immediate availability of project design scope, schedule, and cost information that is high- quality, consistent and reliable."
London, Singh, Taylor, Gu and Brankovic	2008	"An information technology-enabled approach to managing design data in the AEC/FM (Architecture, Engineering and Construction/ Facilities Management) industry."
Kymmell	2008	"A tool helping project teams to achieve the project goals through a more transparent management process based on a three-dimensional (3D) model."
Eastman	2008	"A verb or adjective phrase to describe tools, process, and technologies that are facilitated by digital, mechanic-readable, documentation about building its performance, it's planning, its construction, and later its operation."
Krygiel and Nies	2008	"A creation and use of coordinated, internally consistent, computable information about a building project in design and construction."
Succar	2009	"A set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's lifecycle."
Hardin	2009	"A revolutionary technology and process that has transformed the way buildings are designed, analysed, constructed and managed."

Author	Year	Definition
Zuppa	2009	“A tool for visualising and coordinating AEC works to avoid errors and omissions.”
Eastman, Teicholz, Sacks and Liston	2011	“A ‘generic technology’ that in principle allows many benefits, like more efficiency in construction, fewer mistakes, more accurate and up-to-date information, more illustrative and accessible exposition of the building and its characteristics to all project stakeholders.”
Weygant	2011	“A technology that allows relevant graphical and topical information related to the built environment to be stored in a relational database for access and management.”
Azhar	2011	“A Building Information Model characterises the geometry, spatial relationships, geographic information, quantities, and properties of building elements, cost estimates, material inventories, and project schedule.”
Langdon	2012	“The ability to use and manipulate objects that can have extensive data on a variety of properties associated with them (geometry, connections to other objects, thermal performance, cost, delivery, life expectancy, etc.). And allows designers to produce accurate, coordinated, buildable and robust designs that can be tested in virtual 3D space before they are built.”
NBIMS	2012	“A digital representation of the physical and functional characteristics of a facility creating a shared knowledge resource of information about it, forming a reliable basis for decisions during its life cycle from earliest conception to demolition”.
Ilozor and Kelly	2012	“A myriad of computer software applications that can be utilised by design and construction professionals alike to plan, layout, estimate, detail and fabricate various components of a building.”
HM Government	2012	“A collaborative way of working, underpinned by the digital technologies which unlock more efficient methods of designing, creating and maintaining our assets.”
NHBC	2013	“Building Information Modelling (or ‘management’, more appropriately) is about identifying the important information or data that is used throughout the design, construction and operation of buildings, or any other built asset, and managing it to make it useful to all those involved.”
Miettinen and Paavola	2014	“A digital representation of a building in the form of an object-oriented three-dimensional model, or a repository of project information to facilitate interoperability, automation of processes and exchange of information with related software applications.”
BIMTG	2014	“Essentially a value-creating collaboration through the entire lifecycle of an asset, underpinned by the creation, collation and exchange of shared 3D models and intelligent, structured data attached to them.”
Kim	2014	“An information management system to integrate and manage various construction information throughout the entire construction project life cycle based on a 3D parametric design to facilitate effective communication among project stakeholders to achieve a project goal(s) collaboratively.”

Appendix 3: BIM Research in the Nigerian Context

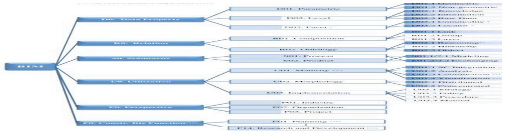
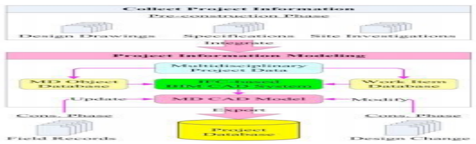
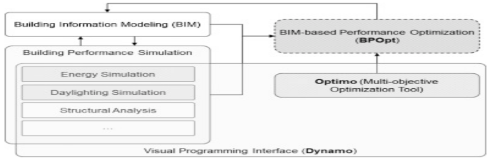
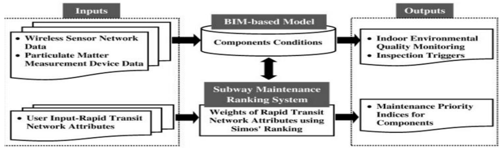
S/No	Authors	Title	Year	Context	Methodology	Findings
1	Oyewole E.O., Dada J.O.	Training gaps in the adoption of building information modelling by Nigerian construction professionals	2019	The purpose of this paper is to assess the training gaps that exist between the perceived and expected knowledge of BIM practice among construction professionals in Nigeria.	The study was carried out through a structured questionnaire survey was systematically collected from 212 participants who are familiar with BIM concepts.	The study reveals that there is a great need to meet the training gaps for BIM adoption in ensuring efficiency of construction project delivery.
2	Ojelabi R.A., Omuh I.O., Afolabi A.O., Tunji-Olayeni P.F.	Assessment of building information modelling uptake in the management of construction projects	2019	This study is aimed at examining the awareness and level of uptake of a digital tool like BIM in the management of construction project and the challenges limiting its use within the built environment.	The study adopted a survey method by randomly selecting 120 construction practitioners in construction firms operating in Lagos state Nigeria. 100 retrieved.	The study revealed that construction organization awareness of the BIM tool is very high, its uptake in the construction industry is not encouraging and the driving factor in encouraging the BIM adoption cut across the government, the construction industry and the clients.
3	Babatunde S.O., Ekundayo D., Babalola O., Jimoh J.A.	Analysis of the drivers and benefits of BIM incorporation into quantity surveying profession: Academia and students' perspectives	2018	This study is to identify and assess the BIM drivers and benefits as important to the QS profession using an empirical approach.	A comprehensive literature review was conducted which was used to design a questionnaire survey targeted to the QS academia 2 Nigerian universities.	The study identified 12 BIM drivers in relation to the QS profession and the analysis of the ranking revealed that almost all the identified BIM drivers are considered by respondents as important.

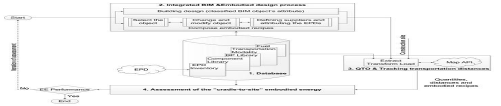
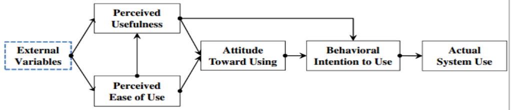
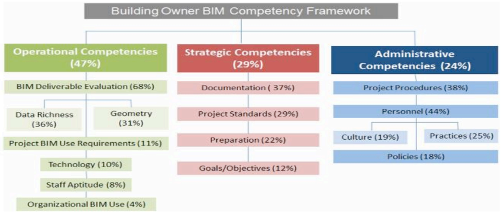
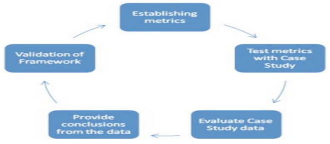
S/No	Authors	Title	Year	Context	Methodology	Findings
4	Ibem E.O., Uwakonye U.O., Akpoiroro G.O., Somtochukwu M., Oke C.A.	Building information 323odelling (BIM) adoption in architectural firms in Lagos, Nigeria	2018	This study was to investigate the impact of BIM, level of awareness, commonly used software, the aspects of architectural work supported by BIM and its benefits in the architectural firms in Lagos, Southwest Nigeria.	The data were collected via a questionnaire survey of 110 architects in Lagos and analysed using descriptive statistics.	The result shows that there is a high level of awareness of BIM, BIM software packages used are Autodesk Revit, Autocad and Sketchup for 2D drawings, 3D visualization, architectural detailing, 323odelling and less of analyses. BIM enhanced the overall productivity of architectural firms.
5	Amuda-Yusuf G.	Critical success factors for building information modelling implementation	2018	This paper expounds the Critical Success Factors (CSFs) for BIM implementation and explore their ranking and underlying relationships.	Survey questionnaire containing these 28 factors was used to collect data from industry practitioners in Nigeria. Benchmark metrics was developed to rank the success factors.	The topmost five success factors for BIM implementation in order of importance are: standard platforms for integration and communication; cost of development; education and training; standardization (product and process); and clear definition and understanding of users' requirement. The five components extracted are: (i) industry stakeholders' commitment and knowledge of BIM, (ii) capacity building for technology adoption, (iii) organisational support, (iv) collaborative synergy among industry professional and (v) cultural orientation.
6	Hamma-adama Mansur,Salman Huda, Kouider Tahar	Diffusion of Innovations: The Status of Building Information Modelling Uptake in Nigeria	2017	Evaluated (BIM) awareness and adoption in Nigeria through 'diffusion of innovations' and its possible uptake.	The study is quantitative using questionnaire survey for the primary data within Nigerian construction industry. Duration of 4 months within North-west, North-central and Lagos.	The study also discovers the most significant barriers to BIM adoption as lack of BIM experts and lack of collaboration by its team stakeholders.

S/No	Authors	Title	Year	Context	Methodology	Findings
7	N. Usman, M. Abubakar and M. A. Ibrahim	Assessment of Some Key Issues that Affect the Acceptance of Building Information Modelling (BIM)	2016	The professionals in the Nigerian construction industry.	Quantitative research design was used, whereby survey was employed using questionnaire as a means of data collection. A total of 190 questionnaire and 1 70 retrieved; SPSS for analysis with descriptive statistic and multiple regression as tools for the analysis.	The finding shows that there is positive relationship between rapid change in technology, cost of integration, government policy and BIM acceptance. It means that rapid change in technology and cost of its integration in conjunction with lack of government enforcement affects BIM acceptance.
8	A. C. Ezeabasili, N.U. Dim, B.U. Okoro	Managing the Change Process Associated with (BIM) Implementation by the Public and Private Investors in the Nigerian Building Industry	2015	Nigerian construction industry professionals associated to PPP.	NO methodology details	The review shows that clients, design team, contractors and the tier suppliers have not heard of BIM before and have no clue what BIM is about. The architects, M&E, and Structural engineers have been using software such as ArchiCAD, and AutoCAD for the design, share a printed copy with General contractor to use on construction site. No software for co-ordination, scheduling and project planning on site used by the General Contractor.
9	Kori Sa'id, Kiv iniemi Arto,	Toward adoption of BIM in the Nigerian AEC industry; context framing, data collecting and paradigm for interpretation	2015	Nigerian Architectural firms that are registered.	The assessment conducted through the survey was explanatory and descriptive by itself. It involved 101 architectural firm registered in Nigeria distributed across selected four cities of	The study shows that most of the medium and larger scale firms are significantly catching up toward the BIM practice, but the small-scale firms are having setbacks especially in the aspect of process and policy adherence. The level of technological workforce toward BIM

S/No	Authors	Title	Year	Context	Methodology	Findings
					Lagos, Abuja, Kaduna and Kano	and digital technology at large was found appreciable.
10	M. Abubakar, Y. M. Ibrahim, D. Kado, and K. Bala	Contractors' Perception of the Factors Affecting Building Information Modelling (BIM) Adoption in the Nigerian Construction Industry	2014	The central issues addressed were the awareness of the respondents on BIM, and their perception on the drivers and barriers to its adoption in the Nigerian construction industry.	The study was undertaken through a survey of Nigerian Building construction firms through administering 100 questionnaire and retrieving 49.	The study highlighted areas requiring attention by researchers, government and other stakeholders towards a country wide implementation of BIM technologies. Education and training were identified as important parts due to the process and technological changes it brings in an organization.

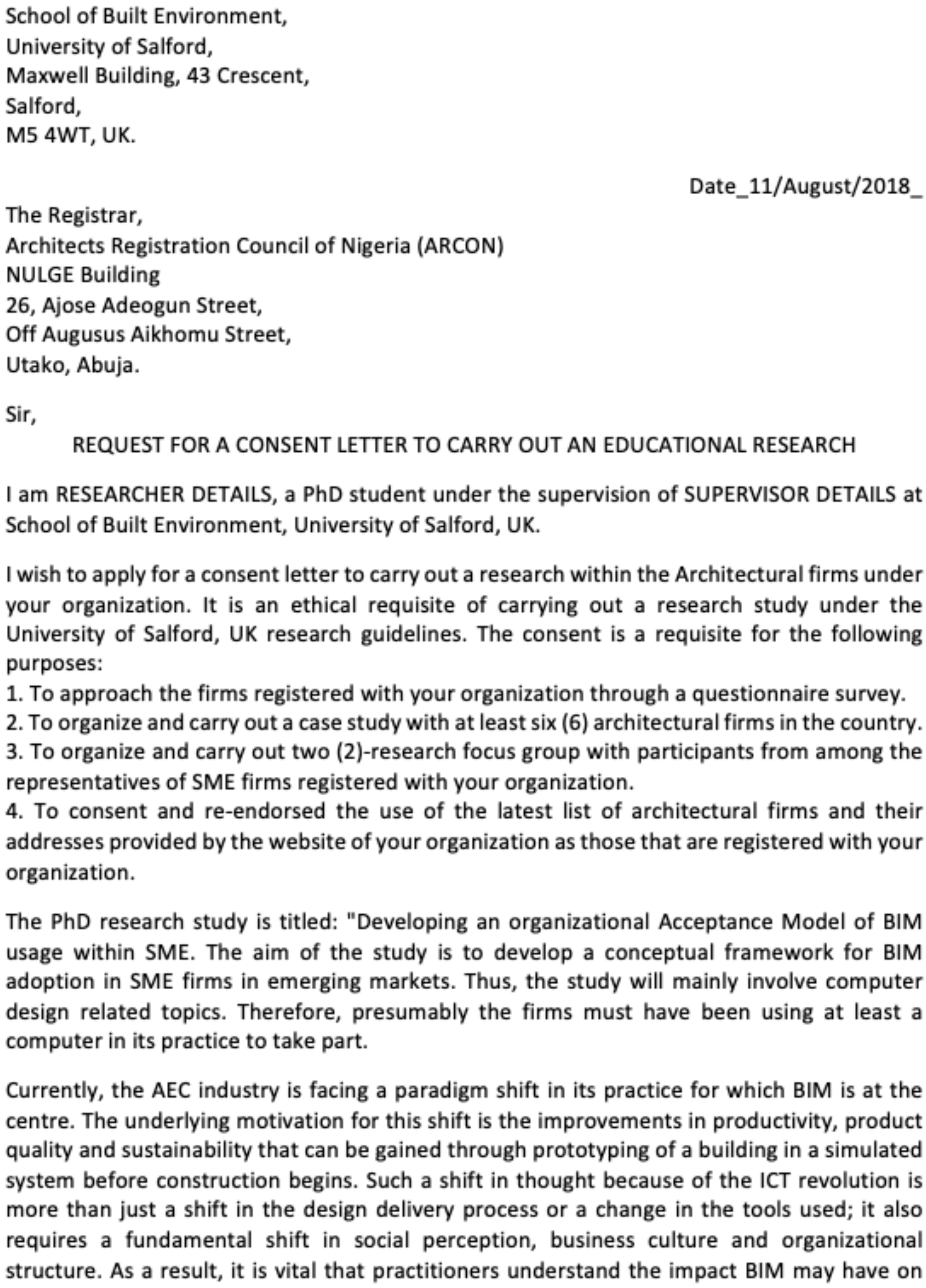
Appendix 4: BIM adoption frameworks

Sample Representation	Abbreviation
 Framework for practical implementation (Jung et al., 2010)	**Framework for practical implementation of BIM:** A review of the current Integrated Building Computer Literature (CIC) and BIM literature was conducted to study the role of BIM from a global perspective. The authors propose a BIM framework that focuses on the practical application of real projects. It consists of 3 dimensions in a hierarchical structure that includes six major variables, namely, the data property, relationship, criteria, usage, perspective, and business function building. This framework can provide a basis for evaluating promising areas and identifying drivers of BIM effectiveness.
 The procedure of project information processing (Feng et al., 2010)	**Use the MD-CAD model to develop an integrated schedule of construction projects:** Time and costs in construction projects are critical determinants of project success. The aim of this research is to develop a model for the scheduling system that can be used to create integrated and costly schedules for construction projects. The model is an extension of 3 BIM applications: a multidimensional CAD model (MD), an object sequence matrix (OSM), and general algorithms (GAs). It provides detailed and targeted information enough to deal with the project thus supports the cost effectiveness of construction projects. Helps reduce overhead and errors and improve project performance by creating flexible and efficient schedules.
 The overview of BPOpt framework (Asl et al., 2015)	**BIM-Based Performance Improvement Framework:** This framework allows designers to explore design alternatives using an open source visual programming interface on the commonly used BIM platform, create models for building design options, and evaluate the environmental performance of these models through cloud computing. Menu simulations and search for the most suitable design alternatives. The framework helps designers (with and without extensive experience in parametric modelling and computer programming) perform a variety of analysis to improve simulation-based design using a BIM-based visual programming interface. The framework was developed as a result of observing gaps in the current literature associated with interdisciplinary improvement in the performance-based design process.
 Schematic diagram for the developed framework (Marzouk et al., 2014)	**BIM-based framework to control the power of metro stations:** The framework was developed to facilitate quality control of the internal environment and to identify maintenance priority indicators for the tested components. The rating system uses the Simos rating method to determine the weights of various components contributing to the overall service level as well as maintenance priority indexes. Maintenance priority indexes are determined based on the conditions stored in the BIM-based model and the weight of the properties. Maintenance Priority Indicators (MPIs) can be calculated globally or locally through the Rapid Transit System. This study developed a measure that allows asset managers to study different funding scenarios by predicting the priority of different components in the network.

Sample Representation	Abbreviation
 Proposed framework for assessment of the "cradle-to-site" embodied impact (Shadram et al., 2016)	**Integrated BIM-based framework to reduce energy consumption during building planning:** This framework is designed to improve interoperability at the design stage of project implementation. It supports planning decisions and enables the assessment of energy in the supply chain of the construction environment. The selection of appropriate criteria usually allows the selection of low impact during the design phase of buildings. The frame also incorporates BIM conversion load technology to enable automated or semi-automated evaluation. A prototype has been developed to improve frame accessibility.
 BIM technology acceptance model (Lee et al., 2015)	**BIM Acceptance Model in Construction Organisations:** This framework is designed to illustrate why BIM should be accredited by a person or institution and what factors drive the BIM application. Identifies factors that influence BIM acceptance from an individual or organizational point of view. Thus, the form can be used to assess the readiness of BIM acceptance for the person and organization. However, this study focuses mainly on the technological perspective. The main components of the framework were identified by examining existing literature on technology acceptance behaviour. The factors involved are used, validated and systematically tested before passing the BIM Acceptance Assessment Framework to users.
 BIMCAT framework (Giel et al., 2015)	**A framework for assessing BIM competencies for manufacturers:** The aim of this research study is to develop a framework that will help construction organizations evaluate their competencies. Provides owners with guidance on how to create a baseline regarding their organization's location and potential areas for improvement. The results of evaluations can help manufacturers expand their technical knowledge, improve their BIM requirements during design and construction, and ultimately improve the efficiency of their operations. Based on existing literature, 66 critical factors affecting the assessment and prioritization of BIM competencies for owners were identified based on the perception of pre-qualified BIM experts. The resulting data were then evaluated using the Delphi method and then used to develop a classification tool that allows owners to evaluate their operations in three different skill areas and 12 specially designed competency categories.
 Framework to measure benefits of BIM (Barlish et al., 2012)	**A framework for measuring the benefits of BIM:** This framework, which was developed to analyse the benefits of BIM and its impact on project efficiency, was developed based on current literature and case studies, some of which were implemented with BIM, others with the traditional non-BIM framework. Approach. Cost and return on investment are also considered when calculating BIM benefits. In general, investment standards consist of planning and construction costs, while return on investment criteria include requests for information, change of requests, and eligibility improvements. In this context, there is great potential for realizing the benefits of BIM, although actual capital returns will vary from project to project.

Source: Adapted from *(Alhusban, 2018)*

Appendix 5: Consent Letter



School of Built Environment,
University of Salford,
Maxwell Building, 43 Crescent,
Salford,
M5 4WT, UK.

Date_11/August/2018_

The Registrar,
Architects Registration Council of Nigeria (ARCON)
NULGE Building
26, Ajose Adeogun Street,
Off Augusus Aikhomu Street,
Utako, Abuja.

Sir,

REQUEST FOR A CONSENT LETTER TO CARRY OUT AN EDUCATIONAL RESEARCH

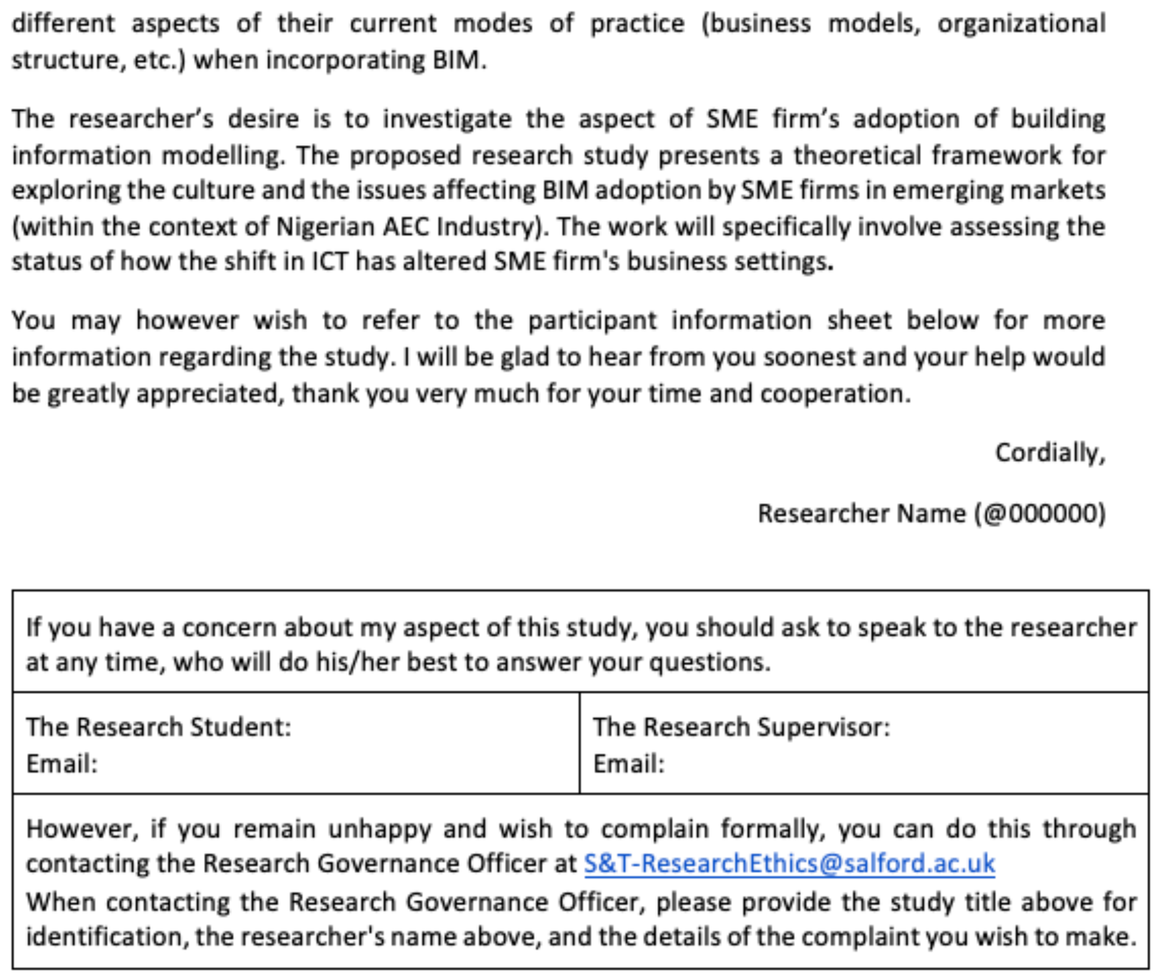
I am RESEARCHER DETAILS, a PhD student under the supervision of SUPERVISOR DETAILS at School of Built Environment, University of Salford, UK.

I wish to apply for a consent letter to carry out a research within the Architectural firms under your organization. It is an ethical requisite of carrying out a research study under the University of Salford, UK research guidelines. The consent is a requisite for the following purposes:

1. To approach the firms registered with your organization through a questionnaire survey.
2. To organize and carry out a case study with at least six (6) architectural firms in the country.
3. To organize and carry out two (2)-research focus group with participants from among the representatives of SME firms registered with your organization.
4. To consent and re-endorsed the use of the latest list of architectural firms and their addresses provided by the website of your organization as those that are registered with your organization.

The PhD research study is titled: "Developing an organizational Acceptance Model of BIM usage within SME. The aim of the study is to develop a conceptual framework for BIM adoption in SME firms in emerging markets. Thus, the study will mainly involve computer design related topics. Therefore, presumably the firms must have been using at least a computer in its practice to take part.

Currently, the AEC industry is facing a paradigm shift in its practice for which BIM is at the centre. The underlying motivation for this shift is the improvements in productivity, product quality and sustainability that can be gained through prototyping of a building in a simulated system before construction begins. Such a shift in thought because of the ICT revolution is more than just a shift in the design delivery process or a change in the tools used; it also requires a fundamental shift in social perception, business culture and organizational structure. As a result, it is vital that practitioners understand the impact BIM may have on



different aspects of their current modes of practice (business models, organizational structure, etc.) when incorporating BIM.

The researcher's desire is to investigate the aspect of SME firm's adoption of building information modelling. The proposed research study presents a theoretical framework for exploring the culture and the issues affecting BIM adoption by SME firms in emerging markets (within the context of Nigerian AEC Industry). The work will specifically involve assessing the status of how the shift in ICT has altered SME firm's business settings.

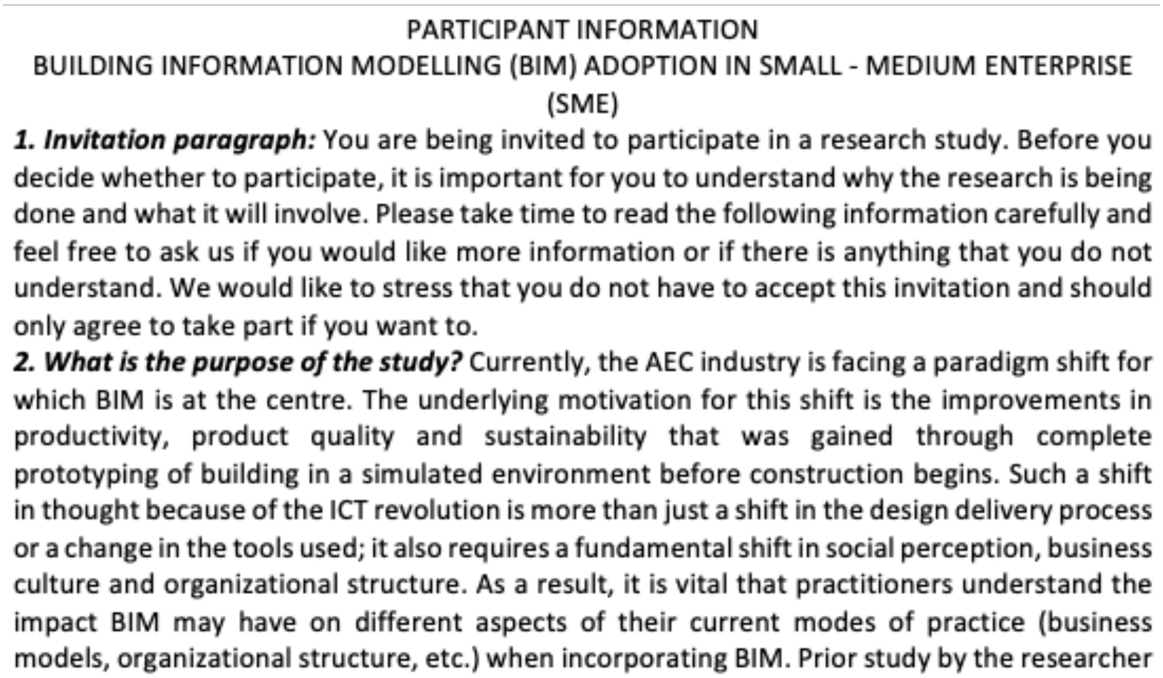
You may however wish to refer to the participant information sheet below for more information regarding the study. I will be glad to hear from you soonest and your help would be greatly appreciated, thank you very much for your time and cooperation.

Cordially,

Researcher Name (@000000)

<table>
<tr><td colspan="2">If you have a concern about my aspect of this study, you should ask to speak to the researcher at any time, who will do his/her best to answer your questions.</td></tr>
<tr><td>The Research Student:
Email:</td><td>The Research Supervisor:
Email:</td></tr>
<tr><td colspan="2">However, if you remain unhappy and wish to complain formally, you can do this through contacting the Research Governance Officer at S&T-ResearchEthics@salford.ac.uk
When contacting the Research Governance Officer, please provide the study title above for identification, the researcher's name above, and the details of the complaint you wish to make.</td></tr>
</table>

Appendix 6: Participant Information Sheet



PARTICIPANT INFORMATION
BUILDING INFORMATION MODELLING (BIM) ADOPTION IN SMALL - MEDIUM ENTERPRISE (SME)

1. Invitation paragraph: You are being invited to participate in a research study. Before you decide whether to participate, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and feel free to ask us if you would like more information or if there is anything that you do not understand. We would like to stress that you do not have to accept this invitation and should only agree to take part if you want to.

2. What is the purpose of the study? Currently, the AEC industry is facing a paradigm shift for which BIM is at the centre. The underlying motivation for this shift is the improvements in productivity, product quality and sustainability that was gained through complete prototyping of building in a simulated environment before construction begins. Such a shift in thought because of the ICT revolution is more than just a shift in the design delivery process or a change in the tools used; it also requires a fundamental shift in social perception, business culture and organizational structure. As a result, it is vital that practitioners understand the impact BIM may have on different aspects of their current modes of practice (business models, organizational structure, etc.) when incorporating BIM. Prior study by the researcher

on overcoming the barriers that affect BIM adoption in small and medium architectural firms instigated the desire to further explore the aspect of SME firms adoption of building information modelling. The proposed research study presents a theoretical framework for exploring the culture and the issues affecting BIM adoption by SME in emerging markets (within the context of Nigerian AEC Industry). The work will specifically involve assessing the status of how the shift in ICT has altered SME architectural firm's business settings in Nigerian AEC industry. The study intends to establish the culture of practice and evaluate the different business models in order to propose a theoretical business model framework of BIM adoption for SME architectural firms in emerging markets. Thus the survey will mainly involve computer design related topics, it is expected that participating firms must have been using at least a computer in its practice to take part.

3. Why have I been chosen to take part? The study aims to examine the culture of practice toward digital technology adoption in Nigeria architectural firms. It involved registered firm by Architectural Registration Council of Nigeria (ARCON). Consent has been received from the council to carry out the research. The council provides the general data such as addresses and official contact details, which were used to contact each organization.

4. Do I have to take part? Your participation is entirely voluntary and you are free to withdraw at any time without giving any reason, without your rights being affected. In addition, should you not wish to answer any particular question or questions, you are free to decline.

5. What will happen if I take part? This study will require that you complete an online questionnaire survey along with any additional comments you want to make. Data for the survey will be collected using the online survey engine hosted by the university server. There are no risk associated in participating, as the survey has been approved by the Institutional review Board of the University of Salford. You will be asked if you are willing to participate in other phases of the research and will be contacted in due course.

6. Expenses and/or payment? No expense or payment are involved in this study.

7. Are there any risks in taking part? No risk involved.

8. Are there any benefits in taking part? We cannot promise that the study will help you directly but the information we get from the study will be used to develop a framework that can help BIM adoption in SME practices in the emerging markets. Moreover, the research is expected to provide information of the state of the art on how the shift of the ICT of the SME is altering the business settings of the firms. The findings will help the discussion on future directions and developments within the industry and in the nation at large.

9. What if I am unhappy or if there is a problem? If you have a concern about my aspect of this study, you should ask to speak to the researcher at any time, who will do his/her best to answer your questions.

The Research Student: Tel: Email:	The Research Supervisor: Tel: Email:

However, if you remain unhappy and wish to complain formally, you can do this through contacting the Research Governance Officer at S&T-ResearchEthics@salford.ac.uk When contacting the Research Governance Officer, please provide the study title above for identification, the researcher's name above, and the details of the complaint you wish to make.

10. Will my participation be kept confidential? All information that is collected during the course of the research will be kept strictly confidential, names and any other information you provide will be kept strictly confidential and will not be attributed to you or your organization either in raw data or in any of the publications The questionnaire responses are stored in the university's secure server. Only the researcher and his supervisor will have access to the data. Respondents contact details will be used in the next phase of the research, after which such data will be destroyed. The results of this research will be used for academic purpose only.

11. What will happen to the results of the study? The result of this research would be purely for educational use, specifically the researcher's PhD thesis and any publication related to it. After the thesis is accepted or the research will be otherwise ended, all the data will be securely destroyed.

12. What will happen if I want to stop taking part? Since the answers will be collected anonymously and the collected data is not connected to the participants, there is no way to remove your data after you have finished your answers and sent them to the server. However, you can stop answering the questionnaire at any point and not send the answers you have given at that point. You can also choose the questions you want to answer and ignore the questions you do not want to answer.

If you want to participate, the next page will contain the final consent information. After accepting the consent, you will be redirected to the actual questionnaire. Thank you.

Appendix 7: Participant Consent Form

PARTICIPANT CONSENT SECTION

1. I confirm that I have read and understood the participant information section for this study. I have had the opportunity to consider the information, ask questions by email and have had these answered satisfactorily.

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my rights being affected in addition, should I not wish to answer any particular question or questions, I am free to decline.

3. I understand that since the answers will be collected anonymously and the collected data is not connected to my contact information, there is no way to remove my data after I have finished my answers and sent them to the server. However, I can stop answering the questionnaire at any point and not send the answers I have given at that point.

4. I understand and agree that once I submit my data it will become anonymised and I will therefore no longer be able to withdraw my data.

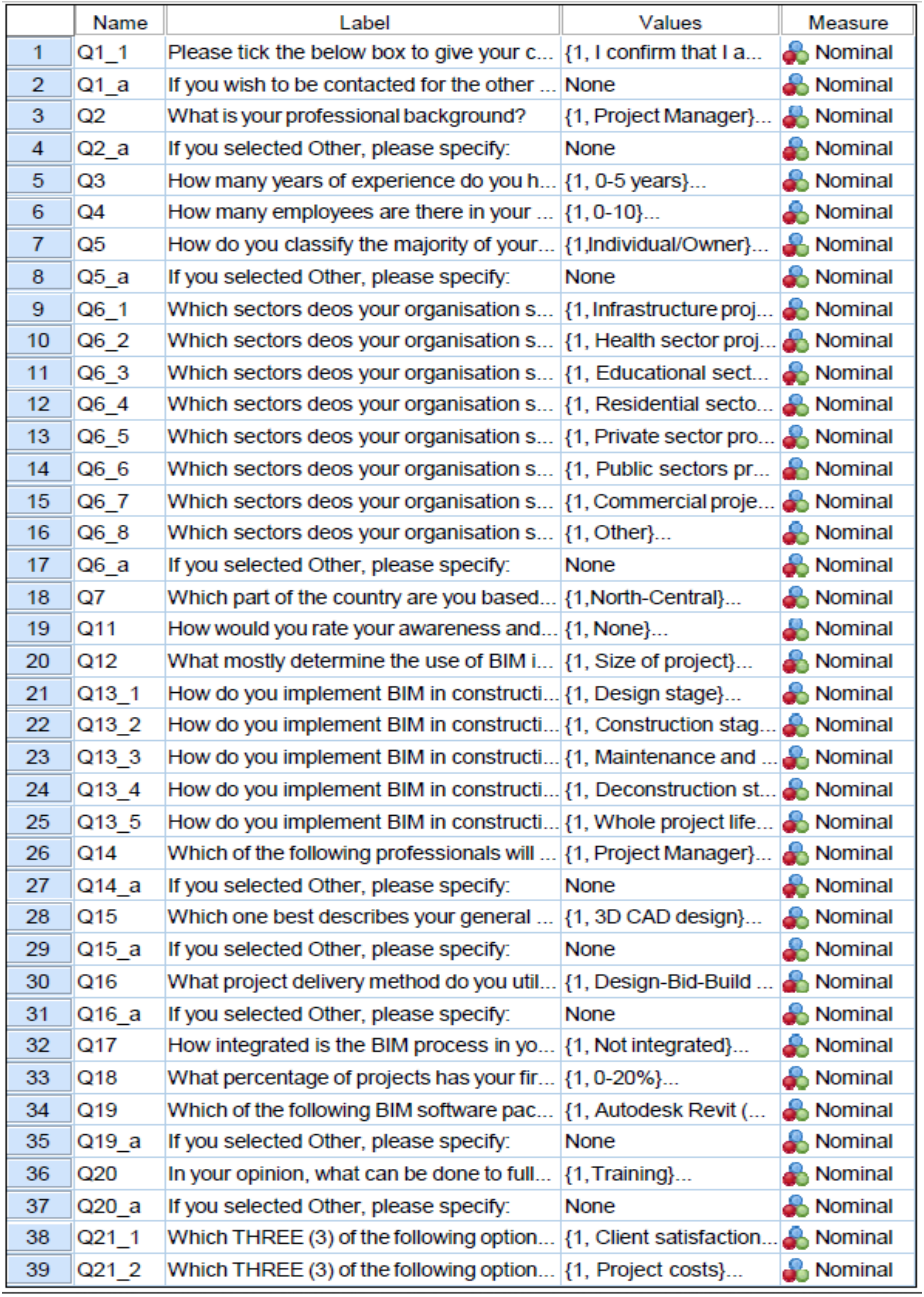
5. I understand that my responses will be kept strictly confidential and I give permission for members of the research team to have access to my anonymised responses. I understand that my name will not be linked with the research material, and my company or I will not be identified or identifiable in the report or reports that result from the research.

6. I understand that I must not take part if I am not using at least computer for any task in the firm I am representing.

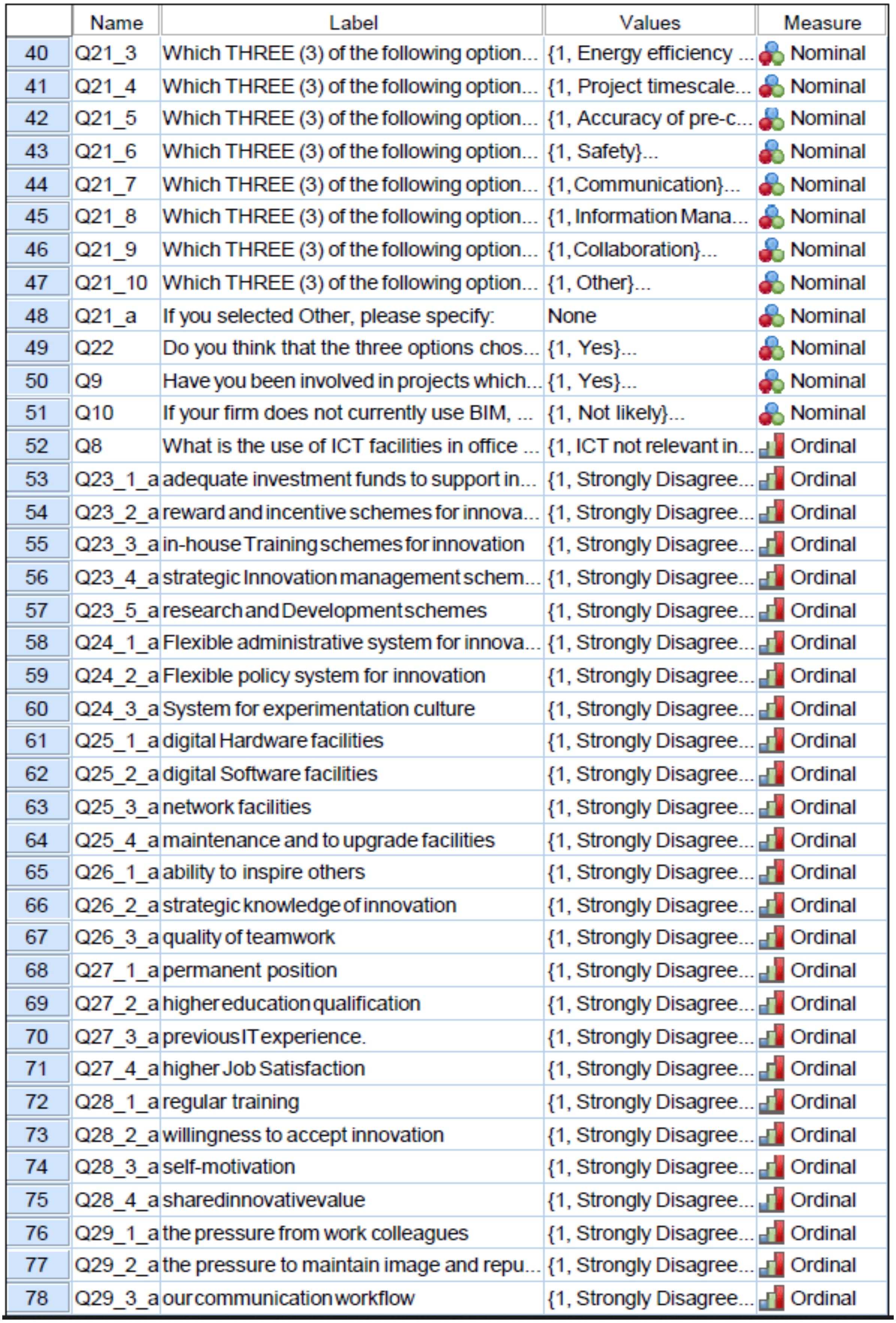
You must tick yes to acknowledge that you fully understand and agree with the above statement before taking part.

I confirm YES to take part in this questionnaire study only	
If you wish to participate in the other part of the study, please enter your contact information.	Email: Tel:

Appendix 8: Coding Sheet



	Name	Label	Values	Measure
1	Q1_1	Please tick the below box to give your c...	{1, I confirm that I a...	Nominal
2	Q1_a	If you wish to be contacted for the other ...	None	Nominal
3	Q2	What is your professional background?	{1, Project Manager}...	Nominal
4	Q2_a	If you selected Other, please specify:	None	Nominal
5	Q3	How many years of experience do you h...	{1, 0-5 years}...	Nominal
6	Q4	How many employees are there in your ...	{1, 0-10}...	Nominal
7	Q5	How do you classify the majority of your...	{1,Individual/Owner}...	Nominal
8	Q5_a	If you selected Other, please specify:	None	Nominal
9	Q6_1	Which sectors deos your organisation s...	{1, Infrastructure proj...	Nominal
10	Q6_2	Which sectors deos your organisation s...	{1, Health sector proj...	Nominal
11	Q6_3	Which sectors deos your organisation s...	{1, Educational sect...	Nominal
12	Q6_4	Which sectors deos your organisation s...	{1, Residential secto...	Nominal
13	Q6_5	Which sectors deos your organisation s...	{1, Private sector pro...	Nominal
14	Q6_6	Which sectors deos your organisation s...	{1, Public sectors pr...	Nominal
15	Q6_7	Which sectors deos your organisation s...	{1, Commercial proje...	Nominal
16	Q6_8	Which sectors deos your organisation s...	{1, Other}...	Nominal
17	Q6_a	If you selected Other, please specify:	None	Nominal
18	Q7	Which part of the country are you based...	{1,North-Central}...	Nominal
19	Q11	How would you rate your awareness and...	{1, None}...	Nominal
20	Q12	What mostly determine the use of BIM i...	{1, Size of project}...	Nominal
21	Q13_1	How do you implement BIM in constructi...	{1, Design stage}...	Nominal
22	Q13_2	How do you implement BIM in constructi...	{1, Construction stag...	Nominal
23	Q13_3	How do you implement BIM in constructi...	{1, Maintenance and ...	Nominal
24	Q13_4	How do you implement BIM in constructi...	{1, Deconstruction st...	Nominal
25	Q13_5	How do you implement BIM in constructi...	{1, Whole project life...	Nominal
26	Q14	Which of the following professionals will ...	{1, Project Manager}...	Nominal
27	Q14_a	If you selected Other, please specify:	None	Nominal
28	Q15	Which one best describes your general ...	{1, 3D CAD design}...	Nominal
29	Q15_a	If you selected Other, please specify:	None	Nominal
30	Q16	What project delivery method do you util...	{1, Design-Bid-Build ...	Nominal
31	Q16_a	If you selected Other, please specify:	None	Nominal
32	Q17	How integrated is the BIM process in yo...	{1, Not integrated}...	Nominal
33	Q18	What percentage of projects has your fir...	{1, 0-20%}...	Nominal
34	Q19	Which of the following BIM software pac...	{1, Autodesk Revit (...	Nominal
35	Q19_a	If you selected Other, please specify:	None	Nominal
36	Q20	In your opinion, what can be done to full...	{1,Training}...	Nominal
37	Q20_a	If you selected Other, please specify:	None	Nominal
38	Q21_1	Which THREE (3) of the following option...	{1, Client satisfaction...	Nominal
39	Q21_2	Which THREE (3) of the following option...	{1, Project costs}...	Nominal



	Name	Label	Values	Measure
40	Q21_3	Which THREE (3) of the following option...	{1, Energy efficiency ...	Nominal
41	Q21_4	Which THREE (3) of the following option...	{1, Project timescale...	Nominal
42	Q21_5	Which THREE (3) of the following option...	{1, Accuracy of pre-c...	Nominal
43	Q21_6	Which THREE (3) of the following option...	{1, Safety}...	Nominal
44	Q21_7	Which THREE (3) of the following option...	{1, Communication}...	Nominal
45	Q21_8	Which THREE (3) of the following option...	{1, Information Mana...	Nominal
46	Q21_9	Which THREE (3) of the following option...	{1, Collaboration}...	Nominal
47	Q21_10	Which THREE (3) of the following option...	{1, Other}...	Nominal
48	Q21_a	If you selected Other, please specify:	None	Nominal
49	Q22	Do you think that the three options chos...	{1, Yes}...	Nominal
50	Q9	Have you been involved in projects which...	{1, Yes}...	Nominal
51	Q10	If your firm does not currently use BIM, ...	{1, Not likely}...	Nominal
52	Q8	What is the use of ICT facilities in office ...	{1, ICT not relevant in...	Ordinal
53	Q23_1_a	adequate investment funds to support in...	{1, Strongly Disagree...	Ordinal
54	Q23_2_a	reward and incentive schemes for innova...	{1, Strongly Disagree...	Ordinal
55	Q23_3_a	in-house Training schemes for innovation	{1, Strongly Disagree...	Ordinal
56	Q23_4_a	strategic Innovation management schem...	{1, Strongly Disagree...	Ordinal
57	Q23_5_a	research and Development schemes	{1, Strongly Disagree...	Ordinal
58	Q24_1_a	Flexible administrative system for innova...	{1, Strongly Disagree...	Ordinal
59	Q24_2_a	Flexible policy system for innovation	{1, Strongly Disagree...	Ordinal
60	Q24_3_a	System for experimentation culture	{1, Strongly Disagree...	Ordinal
61	Q25_1_a	digital Hardware facilities	{1, Strongly Disagree...	Ordinal
62	Q25_2_a	digital Software facilities	{1, Strongly Disagree...	Ordinal
63	Q25_3_a	network facilities	{1, Strongly Disagree...	Ordinal
64	Q25_4_a	maintenance and to upgrade facilities	{1, Strongly Disagree...	Ordinal
65	Q26_1_a	ability to inspire others	{1, Strongly Disagree...	Ordinal
66	Q26_2_a	strategic knowledge of innovation	{1, Strongly Disagree...	Ordinal
67	Q26_3_a	quality of teamwork	{1, Strongly Disagree...	Ordinal
68	Q27_1_a	permanent position	{1, Strongly Disagree...	Ordinal
69	Q27_2_a	higher education qualification	{1, Strongly Disagree...	Ordinal
70	Q27_3_a	previous IT experience.	{1, Strongly Disagree...	Ordinal
71	Q27_4_a	higher Job Satisfaction	{1, Strongly Disagree...	Ordinal
72	Q28_1_a	regular training	{1, Strongly Disagree...	Ordinal
73	Q28_2_a	willingness to accept innovation	{1, Strongly Disagree...	Ordinal
74	Q28_3_a	self-motivation	{1, Strongly Disagree...	Ordinal
75	Q28_4_a	sharedinnovativevalue	{1, Strongly Disagree...	Ordinal
76	Q29_1_a	the pressure from work colleagues	{1, Strongly Disagree...	Ordinal
77	Q29_2_a	the pressure to maintain image and repu...	{1, Strongly Disagree...	Ordinal
78	Q29_3_a	our communication workflow	{1, Strongly Disagree...	Ordinal