IMPACT OF CONSTRUCTION PROFESSIONALS BEHAVIOURAL INTENTION ON BUILDING INFORMATION MODELING (BIM) ADOPTION IN ABUJA, NIGERIA

BY

ISA, Suleiman
MTECH/SET/2019/9772

DEPARTMENT OF QUANTITY SURVEYING
FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGER STATE

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A THESIS SUBMITTED TO THE SCHOOL OF POST GRADUATE STUDIES, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF TECHNOLOGY DEGREE IN QUANTITY SURVEYING.

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ABSTRACT

The use of technology in the Nigerian construction industry has continued to draw the interest of researchers particularly in the area of Building Information Modelling (BIM). Despite the level of awareness of the technology, the implementation of BIM for construction projects is lagging. As a result, this study aims to assess the construction professionals' behavioural intention on BIM adoption in Nigeria from the perspective of the Unified theory of Acceptance and Use of Technology (UTAUT) model with the view to understanding the variables that influence BIM adoption in Nigeria. The study adopted a quantitative research approach which include the use of a questionnaire. The population of the study include construction professionals registered with Federal Inland Revenue Service (FIRS) which is 4,195. The Kothari sample size formula was applied to calculate the sample size of the study (352 professionals). The questionnaire was then served to the professionals in the population randomly and a total of 156 questionnaires representing a 44% response rate were retrieved. The data collected was analyzed using mean score (MS), factor analysis and Partial least-squared structural equation modelling (PLS-SEM). Mean score was used to rank the critical success factors of the intention to use BIM and UTAUT constructs while factor analysis was used to classify the twenty-eight (28) critical success factors identified from the literature into four groups (Organizational-related Factors, Process-related Factors, Customer-related Factors, and Educational Factors). PLS-SEM was used to test the study nine (9) hypotheses. The study revealed the top five critical success factors to include; Training and learning (MS = 4.12; SD = 0.96; $p < 0.05$), Functionality (MS = 4.11; SD = 1.08; $p < 0.05$), 3D visualization, data sharing and BIM platform access (MS = 4.11; SD = 0.80; $p < 0.05$), Ease of use and adoption (MS = 4.11; SD = 0.77; $p < 0.05$), and Standardization (product and process) (MS = 4.06; SD = 0.80; $p < 0.05$). Out of the nine hypotheses, only five (H_1, H_6, H_7, H_8, and H_9) were found to be significant while the rest (H_2, H_3, H_4, and H_5) were insignificant. The PLS-SEM analysis revealed that the constructs predict the dependent constructs substantially; Actual Use of BIM (R^2 = 62.8%), BIM Adoption (R^2 = 73.1%), and Intention to Use BIM (R^2 = 60.1%). This shows that the constructs in the research model have a huge impact on BIM adoption which is the main dependent construct. The study therefore concluded that the poor link between performance expectancy and BIM adoption suggested that professionals in the construction industry are yet to maximize the inherent benefits of BIM. Therefore, the study recommended the government collaborates with stakeholders toformulate appropriate policies and standards to embrace BIM adoption. This study would also serve as a theoretical foundation for future studies and as well assist construction industry stakeholders to develop appropriate policies to improve BIM adoption in Nigeria.

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LIST OF ABBREVIATIONS

AB	BIM Adoption
AU	Actual Use of BIM
AVE	Average Variance Extracted
BCIS	Building Cost Information Service
BI	Behavioural Intention
BIM	Building Information Modelling
CART	Cronbach Alpha Reliability Test
CF or CSF	Critical Success Factors
CIB	International Council for Building
EE	Effort Expectancy
FC	Facilitating Conditions
FIRS	Federal Inland Revenue Service
GDP	Gross Domestic Product
HTMT	Hetrotrait-Monotrait ratio of correlations
IDT	Innovation Diffusion Theory
MS	Mean Score
NBS	Nigerian Bureau of Statistics
NUC	National Universities Commission
PC	Model of Perceived Credibility
PE	Performance Expectancy
PLS-SEM	Partial Least Square Structural Equation Modelling
RICS	The Royal Institution of Chartered Surveyors
SEM	Structural Equation Modelling
SI	Social Influence
SPSS	IBM Statistical Package for Social Sciences
TAM	Technology Acceptance Model
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
UTAUT	Unified Theory of Acceptance and Use of Technology

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The construction industry is responsible for providing adequate infrastructural facilities to support other industries (Edwards *et al.*, 2017; Owusu-Manu *et al*, 2019). As a result, the industry contributes substantially to the economic development of any country. In Nigeria, the construction industry is one of the industries that contribute substantially to economic development (Olanrewaju*et al.,* 2018). It is evident from previous studies that developing countries like Nigeria are hotspots for infrastructural investors. Nonetheless, some critical issues such as time and cost overrun (Bin Seddeeq *et al.*, 2019; IdreesandShafiq, 2021), poor productivity (Loosemore *et al.*, 2021), labour shortage (Pradhananga *et al.*, 2021), material wastage (FayisaandWayessa, 2021) and slow adoption of emerging technologies (Okpala *et al.*, 2021; McNamara andSepasgozar, 2021) can be attributed to the construction industry. Hence, the application of emerging technologies in a meaningful way solves some of the issues in the construction industry (AkdagandMaqsood, 2019).

Over the last decades, the construction industry has undergone several transformations including increasing interest in information technology with the view to improve construction productivity and cost management. The information technology applied in the construction industry includes 3D printing (Pessoa*et al.,* 2021), big data analytics (Aghimien*et al.,* 2021), building information modelling (BIM) (Olanrewaju*et al.,* 2021), digital twin (Opoku *et al.,* 2021), blockchain (Scott *et al.,* 2021) among others. BIM is one of the most researched emerging technologies in the construction industry with diverse applications.

The idea of BIM can be traced to the 1970s when the building description system with simulation capabilities was introduced (Eastman, 1974). The Royal Institution of Chartered Surveyors [RICS] (2014) stated that there is no standard definition for BIM due to its evolving nature. The existing definitions commonly refer to BIM as a "product", "process", "technology", "innovation" or "strategy". BIM encompasses the use of technology through the utilization of information technology in the design, use, interaction, and information exchange between the different entities required in construction project design and construction. BIM acronym can be used interchangeably for Building Information Model, Building Information Modelling, and Building Information Management (Anifowose *et al.*, 2018). Penttilä (2006) expressed that BIM includes an interaction between policies, process, and technology to "*produce a method for managing importance of building design and project data in digital format or virtual through the building life cycle*".

The construction industry started using BIM in mid-2000 (Zhao, 2017) and it has gained momentum among researchers in many developed and developing countries of the world including Dominica Republic (Silverioand Suresh, 2021), Cambodian (Durdyev *et al.*, 2021), Egypt (Marzouk *et al.*, 2021), Pakistan (AkdagandMaqsood, 2019), New Zealand (Doan *et al.*, 2021), China (Cui *et al.*, 2021), United States (MutisandMehraj, 2022), United Kingdom (Dalui *et al.*, 2021), and Seychelles (Adam *et al.*, 2021).

In Nigeria particularly, there has been a lot of studies on the barriers, drivers, and critical success factors influencing BIM adoption in Nigeria (Anifowose*et al*., 2018; Hamma-adamaandKouider, 2019; Babatunde *et al.*, 2020; Olanrewaju*et al.*, 2020a; Olanrewaju*et al*., 2021). Some researchers have as well assessed the competencies of built environment professionals regarding BIM (Olorunfemi, *et al.*, 2021) and the current state of BIM in Nigeria (Olanrewaju *et al.*, 2020b). This is an indication that

BIM is a critical technology that can enhance the Nigerian construction industry by reducing cost, shortening project duration, improving project quality and productivity. However, there are still existing issues affecting its adoption. This calls for an examination of the behavioural intention of construction professionals to use BIM.

1.2 Statement of the Research Problem

BIM is one of the useful technologies in the construction industry that has proven to solve many inefficiencies such as building element clash, cost overrun and project management issues in the construction industry (Pärn *et al.,* 2018). BIM has experienced a great level of awareness over the years in Nigeria and many other developing countries. Despite this level of awareness, the level of BIM implementation on a construction project is low. The only project that has fully implemented BIM in Nigeria is the Eko Atlantic City project (i.e. from design to operation) (Olanrewaju*et al*., 2020b). This has drawn the attention of many researchers that have explored the drivers, barriers, status, and competency issues as regards BIM adoption (Babatunde *et al*., 2020; Olanrewaju*et al*., 2020b; Olorunfemi*et al*., 2021; Olanrewaju*et al*., 2021). Usman *et al.* (2016) have studied the acceptance of BIM among construction professionals in Nigeria and revealed the lack of government policies, rapid change in technology, and cost of BIM integration negatively influence BIM acceptance. Studies have also explored the use of BIM in improving construction health and safety (Ganahand John, 2015; Fargnoli and Lombardi, 2020; Tender *et al.,* 2022).

In recent times, studies in developed and developing countries have started exploring BIM adoption from the perspective of construction professionals' behavioural intention. For instance, Cui *et al.*(2021) studied the use intention of architectural designers' towards BIM in China. Similarly, Wu *et al.*,(2021) investigated BIM adoption in China

based on the theory of planned behaviour (TPB).Abubakar andOyewobi (2019) studied the BIM readiness of construction professionals by applying the Unified Theory of Acceptance and Use of Technology (UTAUT). The study revealed the poor state of BIM readiness of construction professionals in the Northern part of Nigeria. This calls for a more immersive study into the behavioural intention of construction professionals towards BIM.

However, few or no studies have studied the behavioural intention of construction professionals in Nigeria towards the use of BIM. Brown *et al.*,(2002) and Howard *et al.* (2017) emphasized that the attitude of people towards innovation can affect its implementation negatively. This is because the acceptance of an innovation is hinged on individual acts based on their perception of the innovation. This current study contends that the use intention of construction professionals influences the adoption of BIM. The UTAUT theory is more comprehensive compared to the previous technology adoption models this is because Venkatesh *et al.* (2003) combined the previous eight technology adoption models into one model (UTAUT). For this reason, this current study would adopt and modify the UTAUT model to explore the behavioural intention of construction professionals as regards BIM adoption in Nigeria.

1.3 Research Questions

The following research questions have emerged as a result of observations made on the research problem:

1. What are the critical success factors of intention-to-use BIM among construction professionals in the Nigerian construction industry?
2. What are the variables that influence the intention-to-use BIM among construction professionals in Nigeria?

3. What is the impact of construction professionals' use intention on BIM adoption in Nigeria?

1.4 Aim and Objectives of the Study

1.4.1 Aim

The study aims to assess the construction professionals' behavioural intention on BIM adoption in Nigeria from the perspective of the UTAUT model with the view to understanding the variables that hinders BIM adoption in Nigeria.

1.4.2 Objectives

In order to achieve the aim of the study, the following objectives were formulated:

1. To identify the critical success factors of intention-to-use BIM among construction professionals in the Nigerian construction industry;
2. To evaluate the variables that influence the intention-to-use BIM among construction professionals in Nigeria; and
3. To assess the relationship between intention-to-use BIM among construction professionals.

1.5 Research Hypotheses

The hypotheses have been formulated for this study based on the modification to the UTAUT model:

1. **Hypothesis 1 (H_1):** Facilitating condition (FC) has a positive influence on construction professionals' behavioural intention (BI) to use BIM.
2. **Hypothesis 2 (H_2):** Performance expectancy (PE) can improve construction professionals' BI to use BIM.

3. **Hypothesis 3 (H_3):** Effort expectancy (EE) has a positive influence on construction professionals' BI to use BIM.
4. **Hypothesis 4 (H_4):** Social influence (SI) has a positive influence on construction professionals' BI to use BIM.
5. **Hypothesis 5 (H_5):** FC has a positive influence on construction professionals' actual use of BIM.
6. **Hypothesis 6 (H_6):** BI can increase construction professionals' usage of BIM.
7. **Hypothesis 7 (H_7):** Critical success factors of intention-to-use BIM has a positive influence on construction professionals' actual use of BIM.
9. 8.**Hypothesis 8 (H_8):** The actual use of BIM by construction professionals can enhance BIM adoption. **Hypothesis 9 (H_9):** The critical success factors of intention-to-use BIM can positively influence BIM adoption.

1.6 Justification for the Study

Within the last decades, there have been several research works that have been done in the BIM domain globally. This has led to the application of BIM in different contexts including sustainability assessment, clash detection, safety planning, among others (Carvalho *et al.,* 2021; Chahrour*et al*., 2021; Tender *et al.*, 2022). However, the growth of BIM adoption in Nigeria is still lagging despite the various studies that have explored the current state, barriers, drivers, and success factors of BIM. Thus, this study seeks to explore the behavioural intention of construction professionals on BIM adoption by using technology adoption models. Olanrewaju *et al.* (2022) suggested that future studies in Nigeria should explore the adoption of BIM using technology adoption models. This current study is unique in the sense that it studies the impacts of several factors such as behavioural factors and the critical success factors of intention-to-use BIM in the Nigerian construction industry. A thorough understanding of the impacts of

these factors would help enhance BIM adoption in Nigeria and as well help the government formulate critical policies that can stimulate construction professionals' interest in BIM.

1.7 Scope and Limitations

1.7.1 Scope

This research is focused on assessing the behavioural intention of construction professionals towards BIM adoption in Nigeria. Therefore, the scope of this study is limited to the behavioural factors and the critical success factors of intention-to-use BIM that influence BIM adoption. To this end, the research instrument for this study would be distributed to construction professionals in quantity surveying firms, architectural firms, construction firms, government organizations, and other relevant professional bodies in Abuja, Nigeria.

1.7.2 Limitations

The following limitations may be encountered by the researcher, which should affect the research outputs:

1. Inability to reach all the thirty-six (36) States in Nigeria would affect the generalization of the study.
2. Due to the level of BIM adoption in Nigeria, it is anticipated that the expected questionnaires to be returned are going to be very low.
3. It is also anticipated that some knowledgeable construction professionals would be reluctant to fill the questionnaire due to work engagement and other personal reasons.

1.8 Anticipated Findings/Contribution

The model to be developed in this study is critical to improving BIM adoption in Nigeria and other developing countries because it highlights critical factors to BIM adoption such as behavioural factors and the critical success factors of intention-to-use BIM. Policymakers and the government of Nigeria can leverage this model to develop action plans that will facilitate BIM adoption in Nigeria. In addition, this study is the first in Nigeria to explore the behavioural intention of construction professionals using the UTAUT model and include critical variables that influence BIM adoption.

1.9 Structure of the Thesis

This study consists of five (5) chapters ranging from introduction to conclusion. The chapters in the research study are briefly explained as follows including the contents of each chapter as specified in Figure 1.1 which shows the diagrammatic representation of the thesis chapters:

1.9.1 Chapter 1

This chapter deliberated on the background of the study, statement of the research problem, research questions, aim and objectives of the study, research hypotheses, justification for the study, scope and limitations, anticipated findings/contribution, and structure of the thesis.

1.9.2 Chapter 2

This chapter covers the introduction, histories and evolution of BIM, the concept and meaning of BIM, BIM adoption in Nigeria and global context, construction professionals in Nigeria, critical success factors for BIM adoption, drivers of BIM adoption, barriers to BIM adoption, theoretical framework, and conceptual framework.

1.9.3 Chapter 3

This chapter deliberated on the research methodology that is used in this research. It shows a brief introduction, research design, study population, sample frame, sampling technique, sample size, data collection instruments, methods of data analysis, and ethical considerations.

1.9.4 Chapter 4

This chapter showed analyses, presentations, interpretation of results and discussions from which conclusions and recommendations were drawn.

1.9.5 Chapter 5

This chapter deliberate on conclusions, recommendations, limitations, and areas for further study.

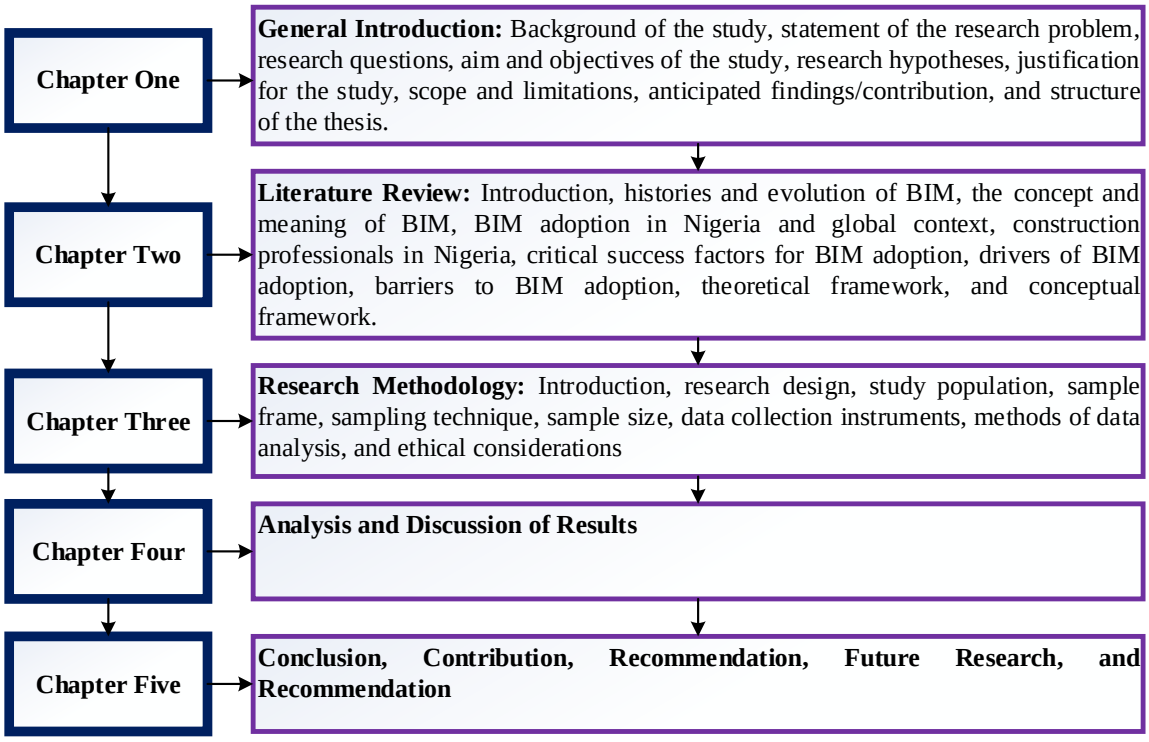

Figure 1.1: Flowchart for Research Outline

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Synopsis of Chapter Two

The construction industry encompassing the Architectural, Engineering and Construction sectors has remained a consistent contributor to the socio-economic survival of nations (Ullah *et al.,* 2019). The construction industry is a significant component of a nation's economic development (Ullah*et al*., 2019) playing a crucial role in spearheading development strides, its ability to greatly impact the gross domestic product of a nation by employing skilled and unskilled personnel cannot be overemphasized, this sector holds great potency in driving the industrialization of a country.

Historically, the construction industry is intrinsically connected with industrialization and urbanization (OsuizugboandOjelabi, 2020). Olanrewaju*et al*. (2018) expounded that the construction industry can be categorized based on the nature of works executed by the different sections within the industry into three which are the building, civil and heavy engineering and specialist contracting works providing plumbing, carpentry, electricity, painting and tiling works (Kheni*et al*., 2008)

The construction industry is one of the sectors with the most impact on the economy of any nation. The importance of the sector is oftentimes dependent on the extent of GDP accruing from the sector and its employability index (Dantata, 2008). The construction industry is saddled with the task of providing infrastructures ranging from social, amenities, and housing to socio-economic development and industrialization (Ruya *et al.,* 2018).

Between 2010 and 2019, the construction industry has shown a steady rise in the volume of Gross Domestic Product with several state-funded projects championing construction and infrastructural development efforts in the nation (Oluwakiyesi, 2011; Olanrewaju*et al*., 2020). This steady rise was halted in 2020 by the global pandemic. In Nigeria, the huge infrastructural deficit and a total infrastructure stock of about 30% of the Nation's Gross Domestic Product (GDP), falling short of the international benchmark of 70% set by the World Bank puts the building subsector of the construction industry under enormous scrutiny. Nevertheless, statistics from the Nigerian Bureau of Statistics (NBS) posited a 3.2% growth annually between 2021 and 2025 for the construction sector (International Trade Administration, 2021) which further enunciates the inherent economic potentials in the industry. This resonates withOlanrewaju*et al*. (2020) who opined that there exist a plethora of untapped potentials in the construction industry. The industry is full of potentials that if properly harnessed can fast-track its drive towards improved opportunities for expansion and greater efficiency (Oluwakiyesi, 2011).

Despite the high flying indexes emanating various challenges that have been highlighted as the cause of the current state of the construction industry, that range from construction costs, environment and green building-related standards (Diaz, 2016). Also, noted by Allen andShakantu (2016) that there is a lack of cooperation, limited trust among the professionals and ineffective communication. The existence and operated in a segmented style with construction information existing in a disjointed and personalized system (Aryani *et al.*, 2014).

Construction projects involve a specific set of objectives and constraints which are specifically unique to each endeavour to be undertaken. This presents a complex set of relationships between parties under different professional backgrounds in a bid to

achieve these project objectives within the ambient of existent constraints. A large volume of information is being generated by these professionals, this oftentimes results in complexities in information management and coordination. The construction industry has been barraged with many problems and is further exacerbated by the errors resulting from the difficulties in communication, coordination and standardization.

2.2 The Concept and Meaning of BIM

In attempts at providing context to BIM several researchers have attempted to capture the functions and capabilities of BIM. BIM is a modelling technology, communication platform and a digital virtual model. Eastman *et al*. (2011) further explained that these abilities are designed and deployed in the management of design and project data, in a bid to ensure efficiency in the design, construction and post-construction phases (Babarinde, 2017). In streamlining the concept of BIM, great difficulties are experienced as the scope, abilities and functions of BIM is still in the evolution phases with new application areas being discovered progressively.

RICS (2014) stated that no particular definition for BIM has been generally agreed to due to the ever-evolving nature of new areas and frontiers creeping into previously determined boundaries. Nevertheless, each definition of BIM is an attempt to capture the characteristics, functions and abilities inherent in the BIM system which is based on individual use.

Hence, the acronym BIM has been used in referring and representing the different meanings and definitions based on the context and content of the application, among these are Building Information models, Building Information Modelling, Building Information Management and Better Information Management (Babarinde, 2017). The definitions of BIM exist in many forms as described below:

1. Bormann *et al*. (2008) defined a building information model as a comprehensive digital representation of a built facility holding a great depth of information captured in a three-dimensional geometry of the building composition at a specified level of detail and information.
2. Holness (2008) defined BIM as the assemblage of a single database of fully united and interoperable information which can be used impeccably and successively by all members of the design, and construction crew and eventually, by facility owners/ operators.
3. Bormann *et al*. (2008) defined BIM as a method that presents media for the profound use of technology in the design, engineering, construction and operation of built facilities.
4. BIM is a digital representation of the physical and functional characteristics of a facility. In further detail, it depicted BIM as a shared knowledge resource for information about a facility providing a reliable basis for decisions during its life cycle; defined as existing from earliest conception to demolition.
5. Snook (2011) described BIM as a digital representation of physical and functional characteristics of a facility by creating a central knowledge repository of information for influencing and directing the decision making during the project's lifecycle, from earliest conception and demolition.
6. Boukara andNaamane (2015) described BIM as an intelligent model-based process that provides insight to help you plan, design, construct, and manage buildings and infrastructure. So BIM goes further than traditional CAD drawings by providing intelligence to individual building components (e.g. windows, walls or chillers) as well as providing system- and building-wide information

and awareness (system flows or building loads) in addition to simple spatial relationships.

7. Onungwa andUduma-Olugu (2017) described BIM as a product of advancements in technology created in enhancing teamwork, collaboration in the design and construction phase. BIM involves a process that acutely simplifies collaboration and information exchange through a project lifecycle through the stages of conception, design, construction, facility management and decommissioning.
8. Gerges*et al*. (2017) described BIM as a procedural and technological alteration in the architectural, engineering and construction industry.
9. Amuda-Yusuf (2018) defined BIM as a methodology deployed in the integration of digital description of relationships existing among building digital objects so that stakeholders can query, simulate and estimate activities and their impacts on the building process as a lifecycle entity.

2.3 Histories and Evolution of BIM

Technology and its application in the 21st century portend great potentials as a turning point for rejigging the traditional processes in the construction industry. Anifowose*et al*. (2018) and Amuda-Yusuf (2018) noted that BIM was developed as part of the gains of information and communication technology's gain of influence in the construction industry, this wave of technological advancement and innovative adoption is not peculiar to the construction sector only. The digitization of production efforts and processes have well been engrained the modus operandi of sectors like manufacturing, automotive and aviation, whilst saying that the construction sector's application of technology is still at a less advanced stage in relative comparison.

The gains harnessed from the implementation of technology to the process have been tremendously outlined by authors such as Adoption of IT tools such as BIM in the construction industry offers tremendous potentials for improved efficiency and cost savings (Tahir *et al*., 2018).

Despite the high and lofty benefits that could be harnessed in the construction sector, the drive for modern technology utilization was observed to be leisurely in the construction industry (Guand London, 2010) in comparison with the manufacturing and automotive industry.

Vogt (2010), explained the evolution of BIM as emanating from the introduction of Computer-Aided Design (CAD) spearheaded by Sketch Pad's Ivan Sutherland in the year 1962. From thence, an upward turn had been noted in the proliferation of these computer-based designs with Autodesk developed a 2D based AutoCAD software which has varying capabilities, which can be progressively improved upon revision by the designer.

Despite the obvious progress noted with the advent of 2D CAD, its inability to carry out conflict and clash detection functions and fragmentation of drawings remained one of the major drawbacks that necessitated the introduction of an improved means of design production. The development of a BIM as opined by Ibrahim and Abdullahi (2016) was in response to mitigating challenges noted in the 2D system necessitated the introduction of a system that bridges the information sharing and communication issues as well as providing a data repository for the storage, collation and control of construction information flow (Eastman *et al*., 2011). BIM's inherent abilities have exceeded just being a drawing and documentation tool, to presenting a more advanced way of collaborative working platform for the construction project team (Chan, 2014).

From inception, BIM centred on visualization of digital objects and production of model information. The creation and utilization of virtual building models were first discussed in the early 1970s by Professor Charles Eastman at the Georgia Tech School of Architecture (Eastman, 1974). Since its conceptualization in the late 1970s, it has undergone several evolutions to include various perspectives to transcend the design, including estimation, construction process, life cycle, performance evaluation and visualization.

The intent of adopting BIM varies from the pre-construction, construction and post-construction phases (Azhar, 2008; Ahmad-Latiffi*et al*., 2013). The construction industry had commenced the usage of BIM in construction projects from the mid-2000s with projects. The term BIM was first employed by researchers (van NederveenandTolman, 1992). The proliferation and dissemination of this term were started by Autodesk who employed the name BIM in referring to 3D geometric representation (which was one of the obvious features of BIM) in a white paper published in 2003.

Macdonald (2011) noted that the True BIM concept includes the process, technology and culture aspects. It was stated that the 'process' for BIM implementation would cover efforts from the professionals, techniques, principles and methods required for ease in implementation of BIM for varied stages. By 'culture', this refers to the changes that would be required in effectively implementing BIM, this would see a shift in the mode of operation of the professionals' day to day executing of construction and pre-construction activities. The professionals have previously operated their activities in an isolated and individualistic approach with layers of information loss and flow restriction in communication, this leads to repetition of efforts by professionals on similar activities. The 'technology' aspect of BIM implementation includes the software,

database and IT hardware required in implementing BIM. There exists a plethora of BIM-enabled software which can include BIM-3D CAD, intelligent parametric objects and as well utilize an internet-enabled or locally stored database.

BIM occupies a focal point in the interactions emanating from the construction process among professionals (Smith andTardiff, 2012). Furthermore, it was stated that the BIM introduced a new model of information sharing and exchange, this communication model is hinged on Foster (2008) proposition of a shift from the layered and segmented information sharing system with an overwhelming number of communication lines among the professionals. BIM was positioned at the centre of communication among professionals working on a project, having all information and data improvement to be made on the Building Information Model which is accessible and editable by the professionals from the database system. BIM operates a database system whereon all information for the project is developed jointly, progressively improved on and operated by the project team. This would see the professionals jointly collaborating and releasing project information to a jointly managed platform.

RICS (2014) provided a categorization for the BIM abilities, it provided different dimensions for BIM operations ranging from the 3D BIM to the 7D BIM. The increase in number is indicative of increased capabilities inherent in the BIM dimension. The most popular capability of BIM was the 3D visualization referred to as the 3D BIM providing more details in comparison with 2D, the visualization is made up of intelligent/smart parametric objects as mentioned in (Ibrahim and Abdullahi, 2016). 4D BIM incorporates project scheduling abilities into the pre-existing 3D visualization ability. 5D BIM captures the 4D BIM Capabilities with estimating abilities and so on.

2.4 BIM Adoption in Nigeria and Global Context

BIM offers tremendous opportunities for addressing the information and communication inefficiencies, wastages and the lack of collaboration at the design and construction stages (Becerik-Gerber and Rice, 2010; Eadie*et al.,* 2013; Eadie *et al.*, 2014). Darwish*et al*. (2020) stated that BIM offers a platform upon which improvements in the method of the work process in a bid to drive efficiency and effectiveness in the construction industry. Kori and Kivniemi (2015) highlighted the benefits that accrue from the adoption of BIM to range from the provision of efficient communication and data exchange system to auto quantification, improved collaboration, coordination of construction documents, improved design visualization and also, clash detection and cost reduction (Eastman *et al*., 2011).

Adoption of BIM has been driven in the global construction industry (Liao andTeo, 2017), the study further established that improved adoption can be achieved by ensuring the government's commitment in encouraging, specify and mandating BIM use in publicly funded construction and building projects as obtainable in the United Kingdom and the United States. Primarily in the US, the public sector has championed the implementation across the states. In 2015, the US National BIM standards were released, this has provided a guideline for BIM standards implementation, this standard applies to planning, design, construction and operation stages in building projects (Cheng Lu, 2015).

The government's intervention in the UK has been directed also towards public-funded projects requiring a minimum of Level 2 collaborative BIM adoption on these projects whilst providing a suite of guidelines in information management for design, construction and operation phases (McAuley*et al*., 2017). In Norway, the public sector is serving as the launching pad for adoption, setting out open standards for BIM starting

from July 2016 (Liao andTeo, 2017), similarly, Denmark has developed a common language and method for defined information exchange and sharing protocols.

However, the use of BIM in Nigeria is still at the early stage and the direction of the construction industry's wide implementation is still being defined (Abubakar*et al*., 2014; Amuda-Yusuf *et al*., 2017). The adoption of BIM by the construction sector holds the potential of delivering 10% savings on construction projects

This presents a sharp contradiction to the efficient means of communication within a project, these inefficiencies in communication has oftentimes resulted in mistakes and errors in the construction process.

BIM is the most recent paradigm shift in the construction industry and the promising concept determines to shape the industry's fragmentation (Zhao *et al.,* 2016). Implementing information systems in the construction industry has drifted from being a luxury to a necessity, enhancement of construction operations' effectiveness remains a great drive towards introduction and adoption of technology (Yung and Gibson, 1999). Adoption and implementation of new technologies provide a viable opportunity for the developing countries to meet up with the dire need for improvement in built environments and urban infrastructure (AkdagandMaqsood, 2019). Techniques for decreasing project costs and time, increasing productivity and quality has been long sought for in the AEC and Construction Industry at large, therefore, the advent, introduction and adoption of BIM would fit into the desired framework for achieving these issues (Azhar, 2011).

Process Digitalization has transformed a wide range of industrial sectors, pioneering notable increments in productivity levels, quality and variance in products (Bormann *et*

al., 2018). Digitalization of the built environment processes is one of the most noticeable paradigm shifts in the construction industry since the first revolution, BIM represents one of the fulcrums on which this change is hinged.

The planning and construction of built facilities is a wholesome task involving the participation of a wide range of stakeholders from different fields of expertise, through this period, continuous-resolution and circulation of construction data among these stakeholders is a key success factor (Bormann *et al*., 2018). Given the voluminous nature of data and information to be exchanged among professionals during the various stages of construction, a loss of information that is germane to the project is inevitable based on the disruptions that occur in the traditional digital information flow. The consequences of this data loss during exchange accumulates to increased cost of reproduction of such data, cost of delays and occasioned wastages resulting from inadequacy of information for the construction executors, these factors are what forms the basis of major construction drawbacks (Eastman *et al*., 2011; Kushwaha, 2016; Aryani*et al*., 2013).

The adoption of BIM would be championed by the need for the resolution of information flow and coordination problems being experienced in the industry (Baddeleyand Chang, 2015). The application of technology has been noted as a focal point of change in reshaping the activities of the construction industry. Yaakob*et al*. (2016) highlighted the various areas of application of BIM in construction to include:

1. Construction visualization
2. Clash/error detection
3. Construction sequencing/ 4dimensional scheduling
4. Cost estimating
5. Facility management

Kori andKiviniemi (2015) succinctly examined the prospects the Nigerian construction sector offers in regards to BIM implementation. It was discovered that the primary adoption of BIM is being championed by the design professionals, the rate of adoption for the construction and post-construction phase varied based on the size of the firm due to the high initial investment required for BIM adoption as outlined in Olanrewaju*et al*. (2020b). Worthy of note also, is that the various deterring factors in BIM adoption stated in Abubakar*et al*. (2014) are still well in operation and the majority of the recommendations of Amuda-Yusuf (2020) in ensuring government participation, regulation and creation of enabling environment for BIM adoption have not been actioned. Nevertheless, it is worthy of note that the level of awareness of BIM technology is on the increase and the resistance to change also fizzling out.

Therefore, Olanrewaju*et al*. (2020b) supported that BIM application in Nigeria has not fully harnessed the potentials obtainable from the full application of BIM to the various aspects of construction procedures. This may stem from the fact that the majority of professionals are only aware of BIM usage at the design stage as BIM-Compliant design software packages are the widely known BIM packages among Nigerian Professionals. Succar (2009) posited that the South African construction industry's adoption of BIM is being hindered majorly by barriers while in Nigeria exists a higher awareness level in comparison with the usage level of BIM by construction professionals.Alufohai (2012) commented that the adoption figures in Nigeria are rather unexpected due to the high awareness level among professionals (with about 65% awareness levels) but very few implementations in their practices. BIM adoption in Nigeria is usually adopted based on the request by building owners and developers with the government taking a back seat in the implementation of BIM for the delivery of public projects.

2.5 Construction Professionals in Nigeria

The construction industry in Nigeria consists of several companies with variances in operations and activities carried out by these firms (Oladinrin*et al.*, 2012; Osuizugbo, 2020). According to Isa *et al.* (2013) construction activities accounts for about 6% of the employment demands of the nations with subsidiary and support activities providing an additional 4% in developing nations. The economic impact of construction activities cannot be streamlined to the direct employment, GDP and revenue accruing to the states due to such activities but holistically the ripple effect flows deep into other service sectors providing services to that indirect employment in construction activities (Ezeokoli*et al*., 2021). The construction industry is a major stakeholder in employment creation in Nigeria, the forms of employment offered by the construction industry range from formal to informal employment.

In the construction industry, the professionals involved in a construction project are often jointly termed as the Building Construction Team (Nwanekezieand Sam-Otunonye, 2019), these are individuals with the requisite training, experience and skills in ensuring the successful delivery of construction projects, they often have disparate technical backgrounds. Aulich (2013) stated that construction professionals refer also to a widespread network of stakeholders whose efforts are intertwined in the process of conceiving, designing, financing, constructing managing, repairing, and renovating a project. Enoma (2005) enunciated that the professionals involved in construction efforts include architects, land and quantity surveyors, structural and service engineers, facilities and construction managers, civil engineers, builders and project managers (Anyanwu, 2013). Nwanekezie and Sam-Otunonye (2019) elaborated on this, providing details on the extent of involvement and activities peculiarly carried out by these professionals notably:

1. **Architect**: the professionals saddled with the task of encapsulating, translating and providing form to the dream of the project client or developer in form of a brief, outline or preliminary design which can be understood and acted on by other professionals in the construction mix. Abdul Aziz (2009) described the roles of an Architect to include planning, designing and oversight functions of a building's construction. These roles would include such as would translate the user's needs into the builder's requirement, possessing an in-depth understanding of the operational codes guiding the existence and functionality of buildings and facilities.
2. **Land surveyor**: this professional has the mandate of the government in determining land boundaries and has custody of land information. The size, topography, geo-referencing and documentation of the features on and beneath a land is determined by the land surveyor. His scope of operation extends further to the construction phase in placing footing, foundations and ensuring proper levels and benchmarks are adopted for construction purposes. The town planner is a herald for the commencement of the building project as his statutory approval guarantees the building's conformity to the planning standards, zoning and geographic masterplan.
3. **The Engineers**: Construction Engineers are saddled with a lot of responsibilities (HussinandOmran, 2009), utilizing the drawing the engineer can transform designs into physical edifices. Designs utilized by the engineer includes architectural, structural, electrical and mechanical; in arriving at these designs various analyses, simulations, and calculations. Similar to the architect's duties the engineer pays a periodic visit to the site to ensure compliance with engineering drawings, schedules and specifications. He also takes responsibility

for modifications and re-design. More specifically, the engineer takes special care in ensuring the structural stability of buildings.

In the modern construction landscape, the responsibilities expected of a Civil Engineer would include design functions, project planning, construction, system operation, maintenance and repair as well as other ancillary services wherewith the expertise of the engineer is required (Bhuruk *et al.,* 2018).

Furthermore, the positions a civil engineer can occupy in a construction project according to Peku (2020) varies from being a site engineer, quality engineer (quality assurance/control officer), structural engineer, building control surveyor, planning engineer.

4. **The Quantity surveyor**: this professional has specialist training in providing professional advice on the costs of construction activities. The quantity surveying term originates from the role and act of quantifying the various resources required in constructing a particular project. Hussin andOmran (2009) highlighted the roles of the quantity surveyor to include cost estimation, budgeting, management and control of costs within construction projects. In execution of their, a wide range of management procedures and tools. On projects with a volumetric proportion of works, the QS would be required to work out the cost planning, value engineering, feasibility studies, cost-benefit analysis, lifecycle costing, valuation and cost estimation (Anyanwu, 2013). The Quantity surveyor is expected to generate bills of quantities from the project's designs and drawings. A QS as construction cost professional who provides measurement and estimates the cost of resources required for construction project execution, and ultimately ensure strict compliance with the budgetary allocations for the project activities and phases. Further to this, O'Brien *et*

al.(2014) observed that the duties of a quantity surveyor are on the constant increase to accommodate functions according to the requirements of the modern construction landscape, these new functions has drifted from the traditional functions to lose adjustment, auditing, dispute resolution and arbitration to project management, information and value management (Baloiand Price, 2003; Elhag*et al*., 2005).

5. **The Builder:** is a professional pitched at the epicentre of construction activities for a building. His roles would revolve around duties aimed at translating designs, drawings, specifications and schedules into a physical and habitable structure. He is in charge of combining all the inputs of production (money, manpower, materials and machinery) successfully to achieve timely and quality project delivery. His area of core professional competencies would include the management of the production process, production of product management documents and carrying out buildability and maintainability analysis (Anyanwu, 2013).
6. **The Estate Surveyor and Valuer:** the major responsibilities of the estate surveyor and valuer are to provide estimates for the rental, sale and capital value of the building development project, this occurs at the post-construction stage of the building when the professional is required to identify potential buyer and occupants as well as ensure the maintenance and operation of the building project or the disposal of the development (Anyanwu, 2013). The functions and duties of the estate surveyor commence on completion of the building, in Nigeria, the estate surveyor and valuer takes on the role of the facility manager whose input would be required from the design as he holds vital input that could

help ensure the optimal yield of the investment committed to a building project as well ensure the optimal functionality for the occupants.

7. **The Project Manager:** he takes on the roles of ensuring compliance with specifications by the contractor, the project manager serves in seeing and catering for the client's direct interests as it affects conformity to standard and client's needs. Anyanwu (2013) stated that the project manager should ensure the cooperation of the contractor(s) in meeting project goals regarding the time, quality and scope. He is appointed to coordinate the consultants, contractor(s) and other stakeholders in the construction project; towards ensuring the project enjoys a seamless execution, he/she will also be a channel through which correspondence will be established and maintained with the client, he is empowered to make and ensure compliance with the client's instructions.

2.6 Critical Success Factors of Intention-to-use BIM

The adoption of building information modelling has opened a vista of prospects to help in efficiently driving construction projects (Darwish*et al.*, 2020). It was also opined that the successful implementation of BIM in construction projects would require a detailed analysis of the influencing success factors. The need to critically analyze the critical success factors in BIM project implementation in construction projects is a major requisite based on the need to ensure the successful completion of projects without being crippled by challenges.

Various researchers have majorly focused on the identification of the various barriers to BIM implementation, Darwish*et al*. (2020), provided justifications on the need to critically examine the success factors as earlier carried out (Ozorhon*et al*., 2017; Ahmed, 2017; Hamada, 2017;andElhendawi, 2018). Amuda-Yusuf (2018) explored the critical success factors affecting BIM implementation collating 28 critical success

factors from previous researches. Phang*et al.* (2020) identified critical success factors influencing BIM adoption in the Precast Concrete Industry. Zezhou*et al*. (2021) also investigated the critical factors of professionals' BIM adoption. Darwish*et al*. (2020) identified critical success factors for BIM for construction projects in the UAE. Furthermore, Yaakob*et al*. (2016) categorized the success factors identified from past literature based on similarities in details, they identified the categories wherein these factors can be classified as shown in Table 2.1.

Table 2.1: Critical Success Factors of Intention-to-use BIM

S/N	Critical Success Factors	Source
CSF1	Interoperability and collaboration	Won *et al*. (2013)
CSF2	Consumer and client requirement	Kori and Kiviniemi (2015)
CSF3	Appropriate hardware and software	Panuwatanich and Peansupap (2013); Bui *et al*. (2016); Amuda-Yusuf (2018)
CSF4	Integration and communication platforms	Amuda-Yusuf, (2018); Kori and Kiviniemi (2015)
CSF5	Culture and structure	Liu *et al*., (2010); Khosroshahi and Arayici (2012); Won *et al*., (2013); Mehran (2016); Liao andTeo (2017); Elhendawi (2018)
CSF6	Training and Learning	; Azhar (2011); Won *et al*. (2013); Bui *et al*., (2016); Amuda-Yusuf, (2018); Olawumi and Chan (2018); Antwi-Afari*et al*. (2018)
CSF7	Communication of BIM objectives/strategy	KhosrowshahiandArayici (2012); Eadie*et al*. (2013); Won *et al*. (2013); Saleh (2015); Mehran (2016);
CSF8	Top Management support	Won *et al*. (2013); Tsai *et al*. (2014a); Love *et al*. (2014); Son *et al*. (2015); Amuda-Ganiyu (2018); Phang (2020)
CSF9	Awareness and experience level	Azhar (2011); Khosrowshahi andArayici (2012); Won *et al*. (2013); Ahmed (2017); Olawumi and Chan (2018)
CSF10	Organizational and staff BIM c ompetencies	Arayici*et al*. (2007); Gu and London (2010); Aryani*et al*. (2012); Tsai *et al*. (2014b); Saleh (2015); Darwish*et al*. (2020);
CSF11	Policy	Brewer and Gajendram, 2011
CSF12	Business process reengineering and coordination	Ugwu andKumaraswamy (2007); Tsai *et al*. (2014b); Mahalingam*et al*. (2015); Jin *et al*. (2017)
CSF13	Standardization (Product and Process)	Amuda Yusuf (2018); Aryani*et al*. (2012)
CSF14	Ease of Use and Adoption	Ugwu and Kumaraswamy (2007); Biu*et al*., (2016); Amuda-Ganiyu (2018)
CSF15	Project Information Coordination	Won *et al*. (2013);Ozorhon and Karahan (2017); Antwi-Afari*et al*. (2018); Phang (2020)
CSF16	BIM adoption strategies	Won *et al*. (2013)
CSF17	Functionality	Brewer andGajendran (2011); Tsai *et al*. (2014a)
CSF18	Management Support	Son *et al*. (2015); Tasi*et al*. (2014)
CSF19	3D Visualization , Data Sharing and BIM Platform Access	Liao and Teo (2017); Amuda-Yusuf (2018)
CSF20	Client requirement and ownership	Chan (2014); Ozorhon and Karahan (2017); Darwish*et al*. (2020)

Table 2.1 Continued: Critical Success Factors of Intention-to-use BIM

CSF21	Commitment	Olatunji (2019)
CSF22	Stakeholders Involvement and Information Sharing	Ugwu and Kumaraswamy (2007); Azhar (2011); Khosroshahi and Arayici (2012); Won *et al*. (2013); Olawumi and Chan (2018); Ozorhon and Karahan (2017)
CSF23	Regulatory agencies participation	Liao and Teo (2017); Phang*et al*. (2020)
CSF24	Government's roles, support and legislation	Won *et al*. (2013); Porwal and Hewage (2013); Chan (2014); Chien*et al*., (2014); Saleh (2015); Mohamed (2018); Elhendawi (2018); Olawumi and Chan (2018)
CSF25	Cost of Development	Bui *et al*. (2016); Amuda-Yusuf (2018)
CSF26	Return on Investment	Won *et al*. (2013)
CSF27	Company' Economic Capabilities	Ding *et al*. (2015).
CSF28	Availability of financial resources	Eastman *et al*. (2011); Won *et al.* (2013); Ozorhon and Karahan (2017)

2.7 Theoretical Framework

In understanding the human perspective towards the adoption of technology, the need to explain the reason(s) for human behavioural patterns comes to the fore. Several human psychological types of research and models have been conducted to allow for an in-depth understanding of how and what influences human behaviour, these models have been applied to the adoption of several innovative technologies in a bid to analyse the critical success factors towards the adoption of such technology.

Primarily, there exist eight theories upon which the study of human behaviour towards the adoption or execution of required behaviour is hinged, these theories have undergone progressive development from the 1960s as more factors influencing the behavioural attitude of humans emerges. These eight theories include the Innovation Diffusion Theory (IDT), Theory of Reasoned Action (TRA), Theory of Planned Behaviour (TPB), The Social Cognitive Theory, The Motivational Model, the Model of Perceived Credibility (PC) Utilisation, Technology Acceptance Model (TAM) and a

combination of the TAM and TPB. For this study, three of these models (Theory of reasoned action, Theory of planned behaviour and Technology Acceptance Model, as well as a hybrid model Unified Theory of Acceptance and Use of Technology), would be considered.

2.7.1 Theory of Reasoned Action (TRA)

The Theory of Reasoned Action (TRA) was developed in 1991 by Martin Fishbein and IcekAjzen (Ajzen, 1991). Khater (2016) explained that the theory is designed to provide an explanation for every human behaviour. This theory stipulates that a person's performance of a specified behaviour according to Trafimow (2009), is hinged on the individual's behavioural intentions (what one intends to do or not to do), furthermore, the behavioural intentions are determined by an individual's attitude (one's evaluation of behaviour) and subjective norm (the individual's evaluation of what is deemed important by others).

Hewavitharan*et al*. (2021) stated that an attitude toward behaviour could be regarded as an evaluation of an individual's negative or positive feeling about performing the targeted behaviour, while the subjective norms represent the individual's observation according to the people in his immediate environment. They further explained that an individual's attitude is influenced by the strength of behavioural beliefs and the evaluation of the potential outcomes of such behaviour; the theory establishes that there exists a relationship between the attitudes and the outcomes of behaviour (Fishbein, 1979), for example, if an individual believes that a favourable outcome would emanate from the adoption of technology, they are more predisposed to accepting the use of such technology. Ajzen (1991) countered by explaining that subjective norms can also greatly influence the performance behaviour of an individual as social pressure can sway the behaviour of an individual against the individual personal attitude.

Chuchinprkam (2005), compared the extent of influence of the internal condition (attitude towards behaviour) against that of the external conditions (subjective norms and motivation to comply), which influences the intentions of an individual.

The conceptual model for this theory was developed by considering two additional variables called perceived personal benefits (PPB) and Attitudes towards digitalization (AD), this presents an interplay of inherent human beliefs and other external factors such as skills, benefits and conditions in the utilization of this theory in the construction sector.

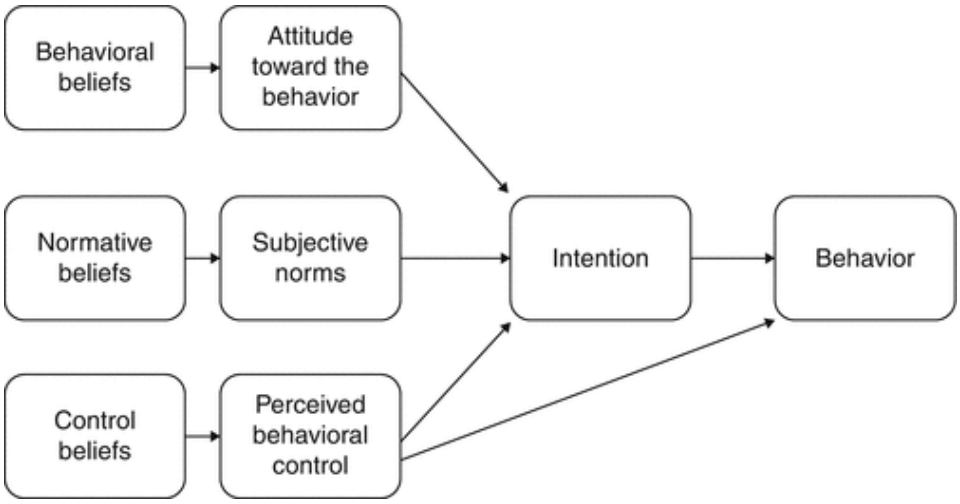

Figure 2.1: Theory of Reasoned Action
Source: Ajzen, (1991); Khater, (2016)

2.7.2 Theory of Planned Behaviour (TPB)

The theory of planned behaviour was introduced by IcekAjzen as an improved version of the Theory of Reasoned Action (TRA) containing various modifications (Ajzen, 1991). This theory was designed to consist of three components which include: behavioural beliefs, Nominative beliefs and Control beliefs (Olabanji, 2019). These factors signify the core beliefs the individual holds towards the outcome of the actions, the influence external parties have on the behaviour as well as the individual's control over the result of such behaviour. Sniehotta (2014) posited that the behavioural beliefs

or attitude of an individual strongly influences an individual's actual behaviour, the negativity or positivity also influences the likelihood of actual performance.

The perceived behavioural control is an addendum to this theory and represents the actual shift from the indicatives captured in Theory of Reasoned Action, this behavioural control presents the degree to which an individual believes he has control over any given behaviour, Ajzen (2011), believed that the behavioural consists of two dimensions namely self-efficacy and controllability. By controllability, refers to the external factors that control behaviour while self-efficacy refers to the level of difficulty required in performing the behaviour or the ability to succeed with that behaviour.

The theory of planned behaviour proposed that the major determinants of an individual's behaviour are behavioural intention and perceived behavioural control. The behavioural intentions are formed based on attitudes towards behaviour (positives or negatives of engaging in the behaviour), Subjective norms associated with the behaviour (other people's beliefs on the behaviour) and the perceived behavioural control (ease or difficulty in performing the behaviour). This perceived behavioural control considers both external and internal factors. The external factors include approval from related parties that eventually shape the individual's belief, Available time also influence an individual's perceived behavioural control; Internal factors that can be considered include the extent to which an individual believes he is in charge of the factors that can guarantee success in line with their knowledge, skills and abilities (Ajzen, 2011; Thomas *et al*., 2013)

The combination of the three beliefs (Behavioural beliefs, nominative beliefs and control beliefs) with positive attitudes and subject norms would see a strong trust in the performance of a specified behaviour, thus strengthening the individual's intention and decision to carry out the behaviour. TPB provides improvements on the determinants

captured in TRA, nevertheless, it had been observed that it does not put into consideration the human emotions often interfacing with the above explained determining factors in behavioural performance (Thomas *et al*., 2013; Hewavitharan*et al*., 2021).

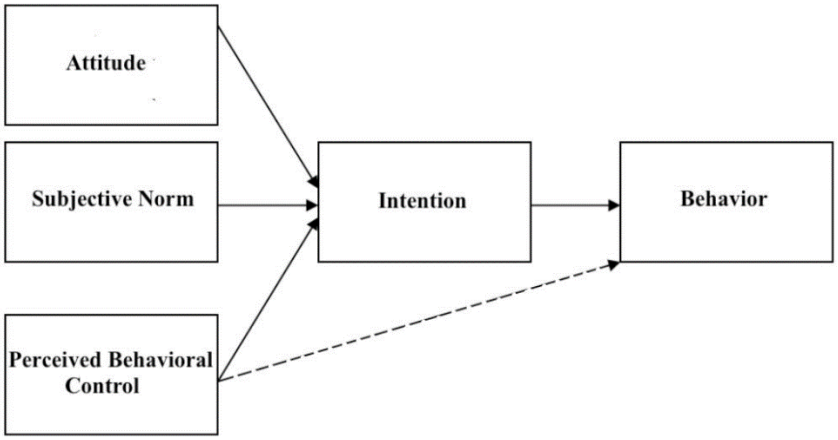

Figure 2.2: Theory of Planned Behaviour
Source: Ajzen (1991); Ajzen (2011); Thomas *et al*. (2013)

2.7.3 Technology Acceptance Model (TAM)

Davis *et al.* (1989) opined that the most vital aspect of an information systems study and execution is its actual reception and usage. Davis *et al*. (1989) proposed the Technology Acceptance Model in 1989 to succinctly explain why people may accept or reject the use of information systems and technology. The actual behaviour an individual exhibits is decided by the behavioural intention which is determined by the attitude and subjective norms, which are in retrospective defined by the beliefs and other factors. This theory is a successor to the theory of reasoned action and theory of planned behaviour, technology acceptance model covers the factors highlight in TRA and TPB in determining the expected behaviour of an individual.

The TAM was specifically designed to study the acceptance of IS technology (Davis,1989), it was designed to provide simplistic explanations on the use of

information systems, providing explanations to the ambiguity in which the TRA and TPB are shrouded. TAM Model is hinged on two factors which are the perceived usefulness and the perceived ease of use, Surendran (2012) explained that the perceived usefulness of a system represents the degree to which a person believes that a system would enhance the execution of his work while Khan*et al.* (2021) enunciated that the perceived ease of use is the degree or extent to which an individual believes that the use of a system would be free of effort. These factors highlighted above come under the influence of external factors such as social, cultural and factors exclusively outside the control of the individuals.

Several types of research have been conducted using TAM to define the different information system types such as E-learning system by teachers, acceptance of online shopping, acceptance of e-commerce, online banking systems, adoption e-service, RFID acceptance was carried out using TAM and modified TAM models (Davis *et al*., 1989; Lokuge*et al*., 2018; GunasingheandNanayakkara, 2021; Hewavithran*et al*., 2021). This model enunciates that the behaviour of an individual is affected by some factors that are beyond his control, hence, the extent to which an individual's desires control his/her behaviour must be understudied.

The TAM model has been noted to contain the following drawbacks, firstly, it does not put into consideration, the deterring factors often associated with the adoption of information systems (Hewavithran*et al*., 2021), also it does not cooperate with other variables that require considerations in perfectly understanding the behavioural intentions, these variables include system design characteristics, top management support, training for staff and decision making characteristics (GunasingheandNanayakkara, 2021).

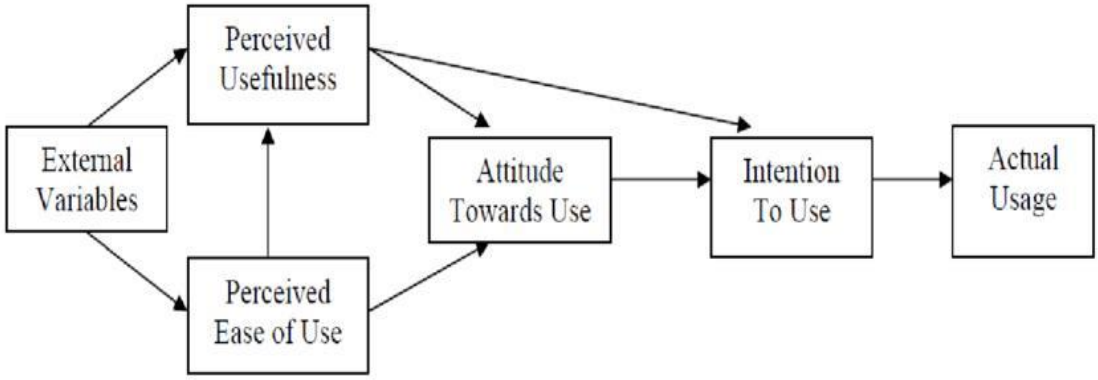

Figure 2.3: Technology Acceptance Model
Source: Davis *et al*. (1989); Sichel (2016)

2.7.4 Unified Theory of Acceptance and Use of Technology (UTAUT)

Venkatesh *et al.* (2003), established the Unified Theory of Acceptance and Use of Technology (UTAUT) model in 2003, this was to eliminate the several disadvantages observed from the utilization of the previously existing eight models especially the Technology Adoption Model (TAM), whilst incorporating social factors and human behaviours in the operation of the model. This model refines, integrates and corroborates the existing theories.

The UTAUT model is a model developed to provide explanations on the intention of the user in the use of information systems and usage behaviour, it is a robust basis for the exploration of a wide range of technology diffusion issues (Wu *et al*., 2021). Hewavitharan*et al*. (2021) explained further that this model presents an evolution of eight other models namely: the Innovation Diffusion Theory (IDT), Theory of Reasoned Action (TRA), Theory of Planned Behavior (TPB), The Social Cognitive Theory, The Motivational Model, the Model of Perceived Credibility (PC) Utilization, Technology Acceptance Model (TAM) and a combination of the TAM and TPB as supported by (Al-Awadhi and Morris, 2008).

The UTAUT model sprung up from the painstaking evaluation and comparative analysis carried out on the existing eight models in the longitudinal field of behavioural studies from whence it was discovered that as against TAM's 40%, the UTAUT model provides about 70% prediction accuracy of Technology acceptance (Holden, 2010). Furthermore, it was noted that indicators such as performance expectancy, effort expectancy, social influence and facilitating conditions greatly influence the user's intention in adopting technology. Asides from the aforementioned reasons, the UTAUT model can be employed to identify the factors critical to ICT acceptance with behavioural intents in the usage of technology and its actual use.

The application of this model has been employed in explaining human conduct across different fields of endeavours with advanced information technology applications such as e-learning, e-governing, e-banking etc. (Waluyani*et al*., 2018; Armenia *et al*., 2021). Hewavitharan*et al*. (2021) applied this model in understanding the human perspective towards digitalization in the construction sector. They further commented that the application of the model has to be uniquely adapted to the peculiarities inherent in the adoption of technology by the construction sector.

In further explanations, Hewavithran*et al*. (2021) highlighted the determinants on which the UTAUT model was developed to include Perceived Usefulness (PU), Perceived Ease of Use (PE), Subjective Norms (SN) and Facilitating Conditions (FC) (Al-Qeisi, 2009; Thomas *et al*., 2013; Al Mansoori, 2017). Perceived Usefulness (PU) explains the individual's belief that the system would help in carrying out their jobs in a more efficient manner; Perceived Ease of Use (PE) connotes the level of ease an individual believes a system would offer in helping them do their jobs; Subjective Norms (SN) indicate whether the individual is concerned about external parties' opinion, and

Facilitating Conditions (FC) verifies if the individual has the requisite personal knowledge and institutional resources required.

Despite the lofty advantages of using this model, its limitation stems from the fact that is designed for a voluntary environment wherein the users decide on the usage of the system does not perfectly align with the BIM environment where adoption and usage of BIM across the construction industry are decided at an organizational level, this would translate to have the adoption of BIM at individual level mandatory. Hence in the use of BIM for measuring adoption behaviours among professionals, the compulsory use of the system should be taken into account in the use of UTAUT models for the professionals (Howard *et al*., 2017).

In a case of mandatory use of technology by an organization, the employees perform their job under the conditions as established by the organization, therefore, their intention would not affect the actual User behaviour of the system, it was suggested that attitude and not the behavioural intentions of the employee would provide a key indicative response as regards to the adoption of such technological process.

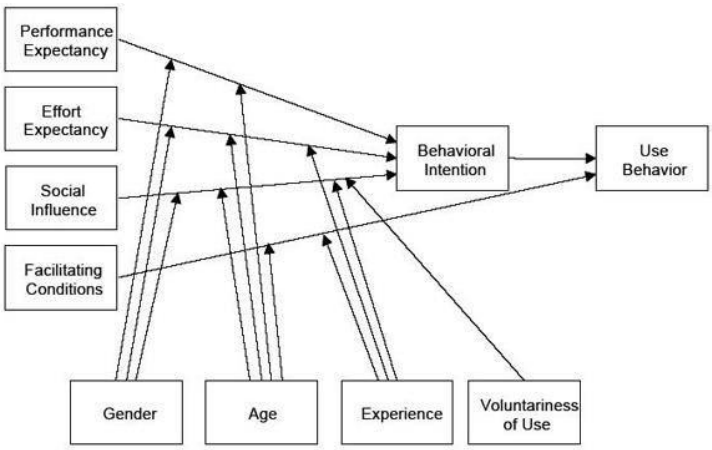

Figure 2.4: Unified Theory of Acceptance and Use of Technology
Source: Davis *et al*. (1989); Sichel, (2016)

2.8 Conceptual Framework

The hypotheses for this study were based on the path relationship by the UTAUT model. The first dependent variable, behavioural intention (BI) also known as "Intention to use BIM" in this study predicts facilitating conditions (FC), performance expectancy (PE), effort expectancy (EE), and social influence (SI). Nonetheless, these variables have a strong influence on BI.

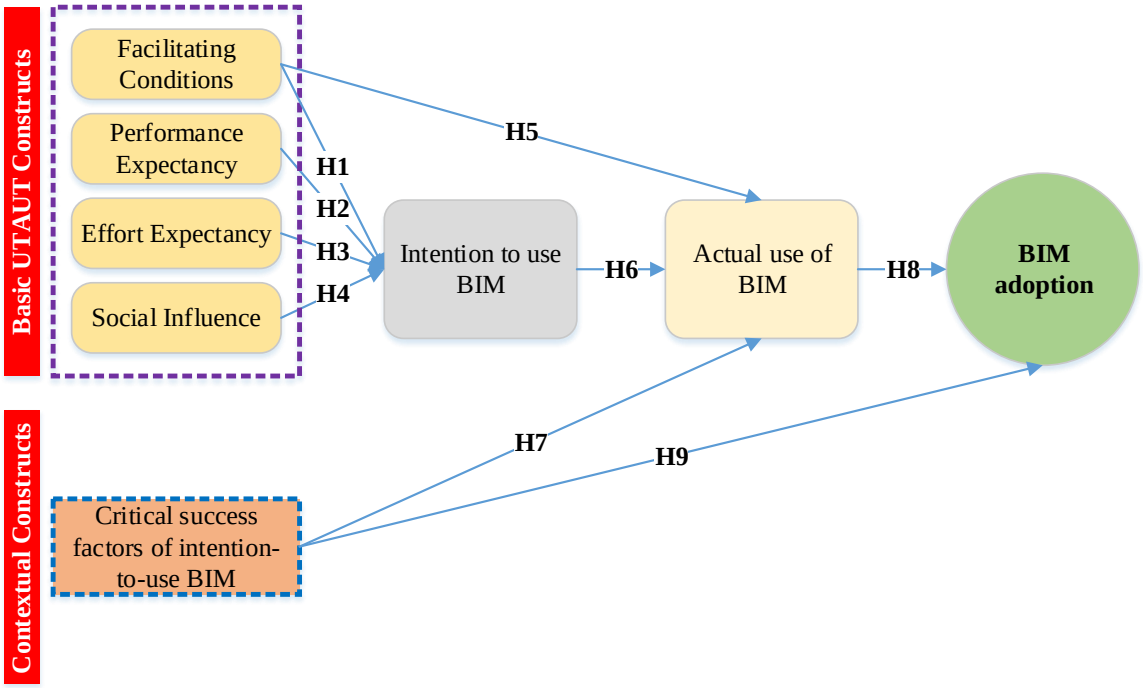

Figure 2.5: Research Conceptual Framework

The hypotheses for this study include the following:

1. **Hypothesis 1 (H_1):** FC has a positive influence on construction professionals' BI to use BIM.
2. **Hypothesis 2 (H_2):** PE can improve construction professionals' BI to use BIM.
3. **Hypothesis 3 (H_3):** EE has a positive influence on construction professionals' BI to use BIM.
4. **Hypothesis 4 (H_4):** SI has a positive influence on construction professionals' BI to use BIM.

The second dependent variable, User Behaviour (actual use of BIM), measures the actual use of BIM by construction professionals. As such, the model predicts that this variable could be influenced by three factors: Facilitating Conditions, Behavioural Intention, and critical success factors of intention-to-use BIM. As a result, the following hypotheses were developed:

5. **Hypothesis 5 (H_5):** FC has a positive influence on construction professionals' actual use of BIM.
6. **Hypothesis 6 (H_6):** BI can increase construction professionals' usage of BIM.
7. **Hypothesis 7 (H_7):** Critical success factors of intention-to-use BIM has a positive influence on construction professionals' actual use of BIM.

The third dependent variable, BIM adoption, measures the actual implementation of BIM in the construction industry. Hence, the model predicts that the variable can be influenced by two factors: actual use of BIM and the critical success factors of intention-to-use BIM. As a result, the following hypotheses were developed:

8. **Hypothesis 8 (H_8):** The actual use of BIM by construction professionals can enhance BIM adoption.
9. **Hypothesis 9 (H_9):** The critical success factors of intention-to-use BIM can positively influence BIM adoption.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Introduction

This chapter explicitly describes all the vital strategies used in achieving the aim and objectives of this research. It focused on the research design, population of the study, sample size and sampling techniques, the instrument for data collection, method of data collection, and method of data analysis. A quantitative research approach was used. The technique for data collection and analyses were explained. The study is descriptive; it is designed to explore the impact of construction professionalsbehavioural intention towards BIM adoption in Nigeria.

3.2 Research Design

Kothari (2004) expressed research design as the arrangement of conditions for the collection and analysis of data in a manner that aims at combining relevance to the research purpose with economy in procedure. Walliman (2011) emphasized that the choice of research design depends on the research problem and aim. This study would adopt the survey design approach which includes the use of a quantitative research approach. The quantitative research approach includes the collection of numerical data to perform mathematical calculations aimed at making reasonable conclusions (Kimmons, 2022). The data would be collected through a questionnaire which will be administered to construction professionals in Abuja with the view to identify the critical success factors of intention-to-use BIM among construction professionals in the Nigerian construction industry; evaluate the variables that influence the intention-to-use BIM among construction professionals in Nigeria; and assess the relationship between intention-to-use BIM among construction professionals.

The research design for this study is divided into five phases, the preliminary phase established background information on BIM adoption and technology adoption models through a review of relevant literature.The next phase focused on the development of questionnaires which was administered to construction professionals in Abuja. The data collection phase deals with the collection of research data. The data analysis and discussion phase deal with the analysis of the collected data and comparison with existing literature to justify findings. The last phase is the conclusion and recommendation phase is which is based on the discussion of the research findings.

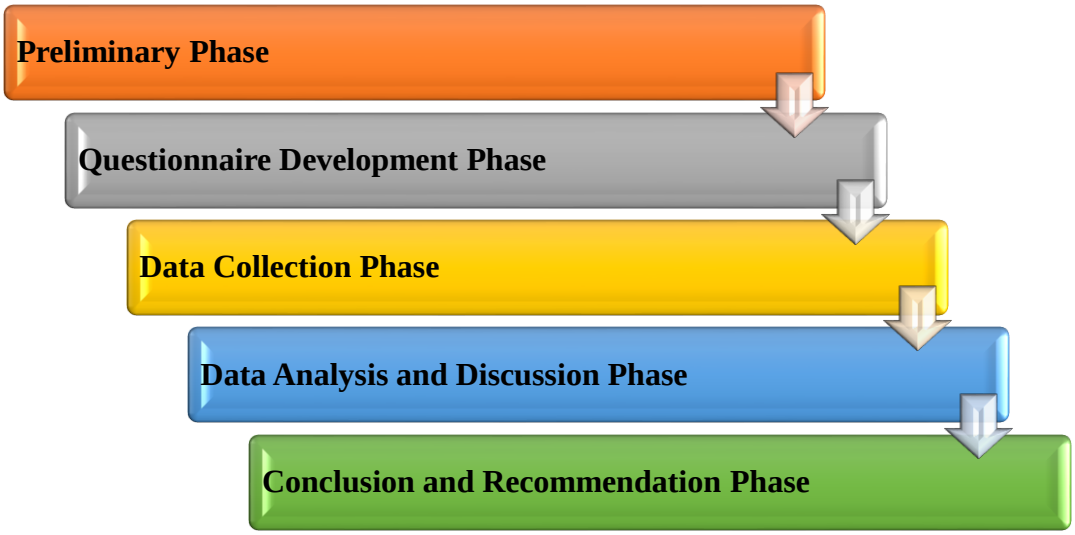

Figure 3.1: Research Design Phases

3.3 Study Population

The study population includes all the construction professionals in Abuja. The list and addresses of construction firms in Abuja on the database of the Federal Inland Revenue Service (FIRS) provided the population for the study. This database was considered credible because it captures professionals that regularly pay their taxes, suggesting that they are active in the field. A total of 4,195 professionals in Abuja were registered on the database as of November 2019.

3.4 Sample Frame

The sample frame refers to the number of individuals that made up the study population that can be sampled by the researcher. In the case of this study, a sampling frame is therefore generated which entails the entire professionals in the project team consisting of the Architect, Builder, Quantity Surveyor, Engineers etc.

3.5 Sampling Technique

The sampling technique is the statistical procedure for choosing a sample or subset from the population of interest for purposes of observations and statistical inferences about that population (Flick, 2018). A simple random sampling technique was used to select construction professionals within Abuja, Nigeria. Each individual is chosen randomly and entirely by chance, such that each individual has the same probability of being chosen (Olanrewaju*et al*., 2018). Although, stratified sampling gives better precision when compared to simple random sampling. There is no official publication to show the number of experienced professionals in the use of BIM. Thus, simple random sampling was selected to give everyone in the population the opportunity to participate in the research if they are knowledgeable about BIM. Simple random sampling has been applied in previous BIM studies (Olanrewaju*et al*., 2020b; Olorunfemi*et al*., 2021; Olanrewaju*et al*., 2021).

However, the selection of the construction professionals was based on the criteria below:

1. The construction professionals should know about BIM.
2. The construction professional must reside within Abuja.
3. The construction professionals should have a reasonable amount of experience in the use of BIM for construction projects.

3.6 Sample Size

Sampling size is the genuine number of sampling made on the aggregate population; this is the extent of the population that was served with the research instruments (Olanrewaju*et al*., 2018). The sample size formula used by Kothari (2004) is given in Equation (1):

$$n = \frac{Z^2 pqN}{e^2(N-1) + Z^2 pq} \qquad (1)$$

Where n is the sample size for the finite population N size of the population; p is the population reliability (or frequency estimated for a sample size n), where p is 0.5 and p+q = 1, e is the margin of error considered as 5% and Z is the normal reduced variable at 0.05 level of significance = 1.96. The sample size for this research is given in Equation (2):

$$n = \frac{1.96^2 \times 0.5 \times 0.5 \times 4195}{0.05^2(4195-1) + 1.96^2 \times 0.5 \times 0.5}$$

$$= 352\ professionals \qquad (2)$$

3.7 Data Collection Instrument

Research instruments are tools used to gather data required for the study to test hypotheses and proffer answers to research questions (Ojo, 2003). A questionnaire was used as a research instrument for this study because it assures the opinion of the targeted respondent. The questionnaires were administered to construction professionals in Abuja that are on the FIRS database.

3.7.1 Questionnaire

A questionnaire is a research instrument used to gather data beyond the physical phenomenon of the researchers (LeedyandOrmood, 2010). A questionnaire survey is easy to be conducted, inexpensive, and suitable for measuring unobservable constructs

(Tharenou *et al.,* 2007). The study obtained quantitative data via the administration of a structured questionnaire. The questionnaire was designed to obtain demographic information and data pertaining to the specific research objectives.Two parts of the questionnaire covering the research goals are included to elicit answers from respondents in the study area. To assess the validity of the information provided, the first section gathered background data from the respondents, including their profession, years of experience, and educational background. The second section gathered information on the critical success factor on the intention to use BIM and evaluate the variables that influence the intention to use BIM among construction professionals as well as to assess the relationship between intention to use BIM among construction professionals. The questionnaire will be distributed face-to-face and through DATAtab. To make sure that information from the questionnaire instrument is properly transmitted and collected for the study.

3.8 Method of Data Analysis

The data obtained were presented and analyzed by IBM statistical package for social sciences (SPSS) version 25, SmartPLS and Microsoft Excel 2016 using descriptive tools. Tables and Graphs were used to present the data gathered in this research. The analysis of the collected data was carried out using the following descriptive tools.

3.8.1 Tables

The table is used to display numeric, non – numeric, discrete, and non – discrete data in an organized manner. It is usually arranged in rows and columns each displaying specific information. This was used in the study to display both collected and analyzed data.

3.8.2 Percentiles

These are ratios used in rating several factors according to the degree of occurrence attached to them. The higher the percentage rating, the higher the importance or significance attached to such factors. Percentile helps to allocate values between 0 and 100 with 100 being the highest value. It can be expressed mathematically as shown below:

$$P = \frac{(n \times 100)}{N}$$

Where;

P = Percentage of the factors

n = size of the factor under consideration

N = total size or population

3.8.3 Reliability analysis

In examining the reliability and consistency internally for the ranking of the results with the Likert-type scale method, Cronbach's Alpha Reliability Test (CART) was employed (Santos, 1999). This test was applied in a bid to assess the validity of the results acquired through the questionnaire survey. The Cronbach's alpha coefficients range from 0 to 1 in value. The threshold reliability coefficient alpha value is 0.70, which means the higher score indicates the adopted measurement scale is reliable (Santos, 1999).

CART is calculated by using the following formula in equation (3) (Cronbach, 1951):

$$\alpha = \frac{n}{n-1}\left(1 - \frac{\sum_i V_i}{V_t}\right) \quad (3)$$

Where, $n = the\ number\ of\ items$

$$V_t = the\ variance\ of\ the\ total\ scores$$

$$V_i = the\ variance\ of\ the\ item\ scores$$

3.8.4 Mean Score and Standard Deviation

Mean score (MS) was used to describe the relative rankings of the critical success factors of intention-to-use BIM from all the respondents in descending order of importance. Recent research on BIM by Olanrewaju*et al*. (2021)have also adopted this method. It is represented mathematically below in equation (4):

$$Mean\ Score\ (MS) = \frac{\sum(f \times s)}{N}, (1 \leq MS \leq 5) (4)$$

Where: s = Score given to each variable by the respondents and ranging from 1 to 5 where "1" means "strongly disagree" and "5" means "strongly agree". f = Frequency of responses to each rating (1 - 5), for each factor N = Total number of responses concerning that variable.

Standard deviation was calculated to obtain the dispersion of the responses regarding the critical success factors of intention-to-use BIM. Standard deviation is calculated by using the following formula in equation (5):

$$\sigma = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}} (5)$$

Where $\sigma = standard\ deviation$

$$\bar{x} = mean\ score$$

3.8.5 Factor Analysis

Factor analysis can be described as a multivariate statistical method that can be applied in many instances (Williams *et al.,* 2010). It is commonly referred to as a data reduction technique that helps reduce a large number of variables into manageable groups. Li *et al.* (2005) opined that factor analysis is used to identify a relatively small number of factor groupings that can be used to represent relationships among sets of many inter-related variables. One of the disadvantages of factor analysis is that it relies on the researcher's ability to develop accurate attributes. Also, there might be difficulties in naming attributes where the results do not generate a meaningful pattern. Factor analysis was applied to classify the critical success factors of intention-to-use BIM into groups.

3.8.6 Structural Equation Modeling

The structural equation modelling (SEM) method shows the relationship between numerous variables and non-observable variables. Amaratunga*et al.*(2010) agreed that SEM is a powerful method for addressing errors in variables. SEM has been applied to study the use intention of construction professionals as regards BIM technology (Cui *et al*., 2021; Wu *et al*., 2021). In order to test the study hypotheses which is aimed at providing the relationships between behavioural intention, actual use, BIM adoption, and the critical success factors of intention-to-use BIM, SEM was applied. The analysis of PLS-SEM consists of two major assessments (measurement model and structural model) (Kineber*et al.*, 2021).

Table 3.1 shows the summary of the analytical tools that will be applied to each of the research objectives.

Table 3.1: Summary of Data Analysis

Objectives	Measurement of variable	Measurement scale	Analytical tool
Section A			
Background information	Descriptive statistic	Nominal scale	Tables Percentiles
Objective 1 To identify the critical success factors of intention-to-use BIM among construction professionals in the Nigerian construction industry.	Descriptive statistic and Likert scale of 5-l	Ordinal scale	Mean ranking Factor analysis
Objective 2 To evaluate the variables that influence the intention-to-use BIM among construction professionals in Nigeria.	Likert scale of 5-l	Ordinal scale	Mean ranking
Objective 3 To assess the relationship between intention-to-use BIM among construction professionals.	Likert scale of 5-l	Ordinal scale	Structural equation modelling (SEM)

CHAPTER FOUR

4.0 DATA ANALYSIS AND DISCUSSION OF RESULTS

4.1 Introduction

The chapter explains the questionnaire data used for analysis including accurate interpretation of the analysis results which is then followed by a discussion of the results obtained from the analysis. The chapter is divided into six key sub-headings (4.1-4.6) which covers introduction, data preparation and reliability, data analysis, structural equation modelling (SEM), discussion of results, and summary of findings.

4.2 Data Preparation and Reliability

Table 4.1 shows the summary of data preparation and reliability. Three hundred and fifty-two (352) questionnaires were administered to the research population and one hundred and fifty-six (156) were retrieved representing a response rate of 44%.

After that, the data was imported into SPSS for analysis to assess its reliability. The main purpose of the reliability test is to assess the reliability and internal consistency of the overall research data. Generally, the reliability in terms of Cronbach Alpha for the entire data (0.784) is good because it is greater than 0.500.

Table 4.1: Summary of Data Preparation and Reliability

Total Responses			Cronbach Alpha
Sent	**Received**	**Response Rate**	
352	156	44%	0.784

4.3 Data Analysis

4.3.1 Demographic characteristics

Table 4.2 shows the demographic characteristics of respondents. As regards educational qualification, 46.15% have a bachelor degree, 8.97% have a Higher National Diploma (HND), 7.05% have a postgraduate diploma, 37.18% have a master degree, while 0.68% have a Doctorate qualification. The revealed that the respondents are adequately educated to provide meaningful information for this research. There is a tendency for this study to be biased towards educated construction professionals, this is because it is difficult for an uneducated person to fill the research questionnaire.Previous BIM-related research works have indicated a high response rate from professionals with a bachelor degree (Olawumiand Chan, 2019; Olanrewaju*et al*., 2020a)

As regards the professional background of the respondents, 41.67% were Architect having a majority, followed by Quantity Surveyor with 32.05%, Engineers with 16%, Estate Surveyor with 5.77% while Builder having minority with 4.49%. The major professions in the Nigerian construction industry are well represented.

For the age group, 44.87% of the respondents were between 21 and 30 years old, 32.05% were between 31 and 40 years old, 10.90% were between 41 and 50 years old and 12.18% were 50 years and above. This shows that almost all age groups are well represented.

In the case of years of experience, 2.56% of the respondents have 10-15 years of working experience, 21.15% have 15-20 years working experience, 54.49% had 5–10 years, 1.92% had less than 5 years working experience while 19.87% have working experience of 20 years and above. This connotes that the respondents are well experienced to provide valuable information for this research.

Regarding firm size, 12.18% are large firms, 61.54% are medium firms while 26.28% are small size firms. Lastly, 87.82% of this firm's main clients are private while 12.18% work for the government.

Table 4.2: Demographics Characteristics of Respondents

Variables		Frequency	Percentage (%)
Highest Academic Qualification	Higher National Diploma	14	8.97
	Bachelor Degree	72	46.15
	Post Graduate Diploma	11	7.05
	Master Degree	58	37.18
	Doctorate Degree	1	0.64
	Total	**156**	**100.00**
Profession	Architect	65	41.67
	Builder	7	4.49
	Engineer	25	16.03
	Estate Surveyor	9	5.77
	Quantity Surveyor	50	32.05
	Total	**156**	**100.00**
Age Group	21-30	70	44.87
	31-40	50	32.05
	41-50	17	10.90
	50 above	19	12.18
	Total	**156**	**100.00**
Years of Experience	10-15 years	4	2.56
	15-20 years	33	21.15
	20 years above	31	19.87
	5-10 years	85	54.49
	Less than 5 years	3	1.92
	Total	**156**	**100.00**
Main Clients	Govertment	19	12.18
	Private	137	87.82
	Total	**156**	**100.00**
Firm Size	Large	19	12.18
	Medium	96	61.54
	Small	41	26.28
	Total	**156**	**100.00**

4.3.2 Critical success factors of intention-to-use BIM

Table 4.3 shows the ranking of the twenty-eight intention-to-use BIM among construction professional implementation according to the mean scores in descending

order. The table also shows that the majority of the hypothesized barriers are perceived as statistically significant ($p< 0.05$) by the respondents using the one-sample t-test value of 3.5. The mean score of the barrier ranges between 3.19 and 4.12. These BIM implementation barriers ranged from "Training and Learning"(mean = 4.12; *SD* =0.96; *t* (155) = 8.09; *p* =0.00 < 0.05) which is the highest ranked to"Communication of BIM objectives/strategy" (mean= 3.19; *SD*= 0.89; *t* (155) = -4.33; *p* = 0.00) which is the least ranked. To get the most significant BIM implementation barriers based on the mean score, a threshold of 3.50 was set. This same threshold approach was used in Olanrewaju*et al*. (2020a) to assess the significant variables. As a result, twenty-one (21) BIM implementation barriers were above 3.50 and considered significant. These implementation barriers include: "Training and Learning" (mean =4.12; *SD* =0.96; *t* (155) =8.09; *p* = 0.00), "Functionality" (mean = 4.11; *SD* =1.08; *t* (155) =7.07;*p* = 0.00), "3D visualization,Data sharing and BIM platform access"(mean =4.11; *SD* =0.80; *t* (155) = 9.51;*p* =0.00). "Ease of use and Adoption" (mean =4.10; *SD* =0.77; *t* (155) =9.69; *p* = 0.00), "Standardization(product and process)" (mean = 4.06; *SD* =0.80; *t* (155) =8.74;*p* = 0.00), "Commitment"(mean =4.03; *SD* =0.84; *t* (155) = 7.80;*p* =0.00). "Availability of financial resources" (mean = 4.01; *SD* =1.01; *t* (155) =6.28;*p* = 0.00), "3D visualization,Data sharing and BIM platform access"(mean =4.11; *SD* =0.80; *t* (155) = 9.51;*p* =0.00). "Company Economic Capabilities" (mean =3.97; *SD* =0.73; *t* (155) =9.69; *p* = 0.00), "Standardization(product and process)" (mean = 4.06; *SD* =0.80; *t* (155) =8.15;*p* = 0.00), "Business process re-engineering and coordination"(mean =3.96; *SD* =0.85; *t* (155) = 6.79;*p* =0.00), "Awareness and experience level"(mean =3.93; *SD* =0.84; *t* (155) = 6.42;*p* =0.00). "BIM adoption strategies" (mean =3.92; *SD* =1.16; *t* (155) =4.47; *p* = 0.00), "Culture and structure" (mean = 3.91; *SD* =0.77; *t* (155) =6.62;*p* = 0.00), "Policy"(mean =3.90; *SD* =0.96; *t*(155) = 5.18;*p* =0.00)."Top

management support" (mean = 3.89; *SD* =1.20; *t* (155) =4.07;*p* = 0.00), "Client requirement and ownership "(mean =3.77; *SD* =1.26; *t* (155) = 2.67;*p* =0.01), "Regulatory agencies participation"(mean =3.67; *SD* =1.80; *t* (155) = 6.42;*p* =0.00). "Return on investment" (mean =3.63; *SD* =1.02; *t* (155) =1.65; *p* = 0.10), "Management support" (mean = 3.62; *SD* =1.04; *t* (155) =1.46;*p* = 0.15), "Cost development"(mean =3.60; *SD* =0.98; *t* (155) = 1.23; *p* =0.22), "Integration and communication platforms" (mean = 3.57; *SD* =1.04; *t* (155) =0.85;*p* = 0.40), "Interoperability and collaboration"(mean =3.52; *SD* =1.16; *t* (155) = 0.21; *p* =0.84).The approach revealed a total of eighteen (18) significant critical success factors to BIM implementation.

Table 4.3: Ranking of the Critical Success Factors of Intention-to-use BIM

S/N	Critical Success Factors	MS	*SD*	t-value (μ = 3.5)	*df*	Sig. (2-tailed)	R
CSF6	Training and learning	4.12	0.96	8.09	155	0.00*	1
CSF17	Functionality	4.11	1.08	7.07	155	0.00*	2
CSF19	3D visualization, data sharing and bim platform access	4.11	0.80	9.51	155	0.00*	3
CSF14	Ease of use and adoption	4.10	0.77	9.69	155	0.00*	4
CSF13	Standardization (product and process)	4.06	0.80	8.74	155	0.00*	5
CSF21	Commitment	4.03	0.84	7.80	155	0.00*	6
CSF28	Availability of financial resources	4.01	1.01	6.28	155	0.00*	7
CSF27	Companyeconomic capabilities	3.97	0.73	8.15	155	0.00*	8
CSF12	Business process reengineering and coordination	3.96	0.85	6.79	155	0.00*	9
CSF9	Awareness and experience level	3.93	0.84	6.42	155	0.00*	10
CSF16	BIM adoption strategies	3.92	1.16	4.47	155	0.00*	11
CSF5	Culture and structure	3.91	0.77	6.62	155	0.00*	12
CSF11	Policy	3.90	0.96	5.18	155	0.00*	13
CSF8	Top management support	3.89	1.20	4.07	155	0.00*	14
CSF20	Client requirement and ownership	3.77	1.26	2.67	155	0.01*	15
CSF23	Regulatory agencies participation	3.67	1.15	1.80	155	0.07	16
CSF26	Return on investment	3.63	1.02	1.65	155	0.10	17
CSF18	Management support	3.62	1.04	1.46	155	0.15	18
CSF25	Cost of development	3.60	0.98	1.23	155	0.22	19
CSF4	Integration and communication platforms	3.57	1.04	0.85	155	0.40	20
CSF1	Interoperability and collaboration	3.52	1.16	0.21	155	0.84	21
CSF15	Project information coordination	3.49	1.23	-0.13	155	0.90	22
CSF3	Appropriate hardware and software	3.48	1.09	-0.22	155	0.83	23
CSF2	Consumer and client requirement	3.43	1.22	-0.72	155	0.47	24
CSF24	Government's roles, support and legislation	3.34	1.16	-1.72	155	0.09	25
CSF10	Organizational and staff BIM competencies	3.33	1.09	-1.98	155	0.05*	26
CSF22	Stakeholders involvement and information sharing	3.23	1.30	-2.58	155	0.01*	27
CSF7	Communication of BIM objectives/strategy	3.19	0.89	-4.33	155	0.00*	28

Note:*SD* = Standard Deviation; R = Rank; Sig. = Level of significance; MS = Mean score of the Critical Success Factors of Intention-to-use BIM among Construction Professionals where 5 = strongly agree; 4 = agree; 3 = neutral; 2 = disagree; 1 = strongly disagree. The higher the mean score the more severe the barrier; df= degrees of freedom, *Significant at the 95 per cent level ($p < 0.05$)

To test the appropriateness of the data for further analysis, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (MSA) and Bartlett test of sphericity (BTS) was

conducted as shown in Table 4.4. These two tests provide the minimum standard that the data should meet to be considered adequate for further analysis. The value of the KMO can vary between 0 and 1, with 0.50 suggested as a minimum (Hair*et al.*, 2010). The Bartlett test indicates whether the correlation matrix is significantly different from the identity matrix (i.e. matrix in which all of the diagonal elements are 1 and other elements are 0). The Bartlett test indicates the strength of the relationship among variables and the significant level of Bartlett's test is a requirement for the data to be considered suitable for analysis. The KMO value was 0.831 which is above 0.50 and the BTS value was found to be significant at $p = 0.000$. The KMO value of 0.831 is greater than the recommended value of 0.600 (Kaiser, 1970; 1974) and Bartlett's Test of Sphericity (Bartlett, 1954) reached statistical significance, supporting the factorability of the data.

Table 4.4: KMO and Bartlett's Test for Critical Success Factors of Intention-to-use BIM

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.831
Bartlett's Test of Sphericity	Approx. Chi-Square	2427.093
	Df	378
	Sig.	.000

Table 4.5 shows the total variance explained for the critical success factors of intention-to-use BIM. Table 4.5 shows the percentage of variance for initial Eigenvalues and rotation sums of squared loadings. For initial Eigenvalues, the percentage of variances from components 1 to 4 are 32.648, 9.158, 7.543, and 5.394 respectively. Regarding,rotation sums of squared loadings, the percentage of variances from components 1 to 4 are 23.404, 14.360, 9.084 and 7.896 respectively.

Table 4.5: Total Variance Explainedfor Critical Success Factors of Intention-to-use BIM

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	9.141	32.648	32.648	6.553	23.404	23.404
2	2.564	9.158	41.807	4.021	14.360	37.764
3	2.112	7.543	49.350	2.543	9.084	46.848
4	1.510	5.394	54.744	2.211	7.896	54.744
5	1.345	4.802	59.546			
6	1.231	4.395	63.940			
7	1.084	3.873	67.813			
8	.990	3.537	71.350			
9	.925	3.302	74.652			
10	.769	2.745	77.396			
11	.700	2.500	79.896			
12	.609	2.175	82.071			
13	.592	2.113	84.183			
14	.536	1.914	86.097			
15	.465	1.662	87.759			
16	.442	1.580	89.339			
17	.386	1.380	90.719			
18	.369	1.319	92.038			
19	.337	1.205	93.242			
20	.319	1.141	94.383			
21	.285	1.017	95.400			
22	.257	.919	96.318			
23	.242	.865	97.183			
24	.213	.761	97.944			
25	.208	.744	98.688			
26	.157	.562	99.251			
27	.126	.451	99.702			
28	.083	.298	100.000			

Extraction Method: Principal Component Analysis.

Figure 4.1 shows the scree plot for factor analysis of the critical success factors of intention-to-use BIM. It can be deduced that the first two components with eigenvalue between 2 and 10 are reliable because it is along the vertical side of the chart while the reliability of the other components diminishes as the component increases. In this study, the first four components are reliable to a good extent because they are along the elbow of the scree plot.

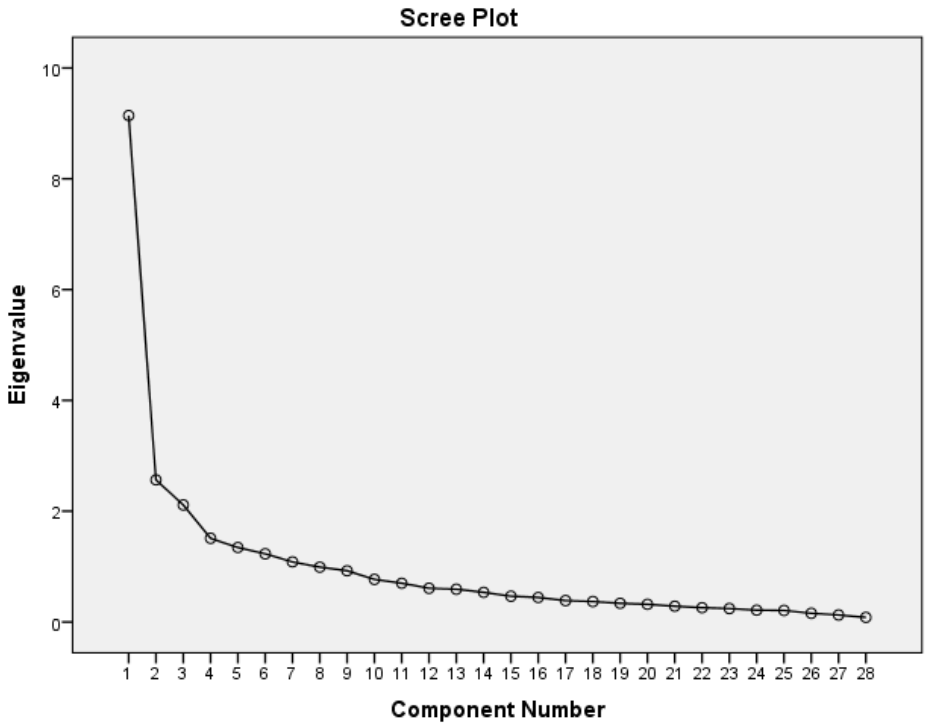

Figure 4.1: Scree Plot for the Critical Success Factors of Intention-to-use BIM

Table 4.6 shows the summary of the Rotated Factor Matrix for the critical success factors of intention-to-use BIM. The factor analysis was performed following Principal Component Solution with a Varimax Rotation (Kaiser, 1958). The data fed into Factor analysis consisted of the data obtained from 156 respondents. The twenty-eight (28) critical success factors were extracted into four fixed components. To retain different factors from the variable taken in this study, the cutting point of eigenvalue was taken

are equal to one. These component factors were further rotated by varimax solution (Olanrewaju*et al*., 2020a). The discussion of the result has been based on the varimaxrotated factor matrix. To discuss the result of the factor matrix, the factor loading of 0.50 or above is considered to be significant. However, the factor loading (except those less than 0.5) of the critical success factors are categorized based on components. Component 1 consists of eleven significant factors with factor loadings ranging from 0.723 to 0.794, Component 2 consists of six significant factors with factor loadings ranging from 0.584 to 0.726, Component 3 consists of four significant factors with factor loadings ranging from 0.514 to 0.761, and Component 4 consists of three significant factors with factor loadings ranging from 0.536 to 0.686.To better contextualize the components, the components were renamed based on the factors under each of them as shown below:

1. **Component 1** which include CSF1 (interoperability and collaboration [0.794]), CSF2 (consumer and client requirement [0.715]), CSF3 (appropriate hardware and software [0.752]), CSF4 (integration and communication platforms [0.728]), CSF8 (top management support [-0.616]), CSF17 (functionality [-0.529]), CSF21 (commitment [-0.525]), CSF23 (regulatory agencies participation [0.754]), CSF24 (government's roles, support and legislation [0.775]), CSF25 (cost of development [0.723]), and CSF26 (return on investment [0.660]) was renamed as "***Organizational-related Factors***".
2. **Component 2** which include CSF11 (policy [0.673]), CSF12 (business process reengineering and coordination [0.584]), CSF13 (standardization (product and process) [0.688]), CSF14 (ease of use and adoption [0.629]), CSF15 (project information coordination [0.726]), and CSF22 (stakeholders involvement and information sharing [0.610]) was renamed as "***Process-related Factors***".

3. **Component 3** which include CSF7 (communication of BIM objectives/strategy [0.514]), CSF16 (BIM adoption strategies [0.624]), CSF18 (management support [0.757]), and CSF20 (client requirement and ownership [0.761]) was renamed as "***Customer-related Factors***".
4. **Component 4** which include CSF6 (Training and Learning [0.686]), CSF9 (Awareness and experience level [0.536]), and CSF28 (Availability of financial resources [0.652]) was renamed as "***Educational Factors***".

Table 4.6: Rotated Component Matrix for the Critical Success Factors of Intention-to-use BIM

S/N	Critical Success Factors	Component			
		1	2	3	4
CSF1	Interoperability and collaboration	.794			
CSF2	Consumer and client requirement	.715			
CSF3	Appropriate hardware and software	.752			
CSF4	Integration and communication platforms	.728			
CSF5	Culture and structure				
CSF6	Training and learning				.686
CSF7	Communication of BIM objectives/strategy			.514	
CSF8	Top management support	-.616			
CSF9	Awareness and experience level				.536
CSF10	Organizational and staff BIM competencies				
CSF11	Policy		.673		
CSF12	Business process reengineering and coordination		.584		
CSF13	Standardization (product and process)		.688		
CSF14	Ease of use and adoption		.629		
CSF15	Project information coordination		.726		
CSF16	BIM adoption strategies			.624	
CSF17	Functionality	-.529			
CSF18	Management support			.757	
CSF19	3D visualization, data sharing and bim platform access				
CSF20	Client requirement and ownership			.761	
CSF21	Commitment	-.525			
CSF22	Stakeholders involvement and information sharing		.610		
CSF23	Regulatory agencies participation	.754			
CSF24	Government's roles, support and legislation	.775			
CSF25	Cost of development	.723			
CSF26	Return on Investment	.660			
CSF27	Company' economic capabilities				
CSF28	Availability of financial resources				.652

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Rotation converged in 6 iterations.

4.3.3 Variables influencing the intention-to-use BIM (UTAUT construct)

Table 4.7 illustrates the descriptive statistics for the UTAUT construct. it shows the ranking of the factors with respect to the mean scores in descending order. The table also shows that all the hypothesized solutions are perceived as statistically significant ($p < 0.05$) by the respondents using the one-sample t-test value of 3.5. The mean score of the variables under "***Facilitating conditions***" ranges between 3.40 and 3.96. These variables ranged from "My clients have an interest in the use of BIM*"* (mean = 3.96; *SD* = 0.074; *t* (155) = 7.75; *p* = 0.00 < 0.05) which is the highest-ranked to "BIM is compatible with other system that I use" (mean = 3.40; *SD* = 1.22; *t* (155) = -1.05; *p* = 0.29 > 0.05) which is the least ranked. To get the most significant experiences based on the mean score, a threshold of 3.5 was set with a reference to the *p*-value which should be less than 0.05 for each of the significant variables. Therefore, only three (3) of these facilitating condition variables were considered significant because they were above the set 3.5 thresholds.

The mean score of the variables under "***Performance Expectancy***" ranges between 3.11 and 4.13. These variables ranged from "Using BIM is of benefit to me*"* (mean = 4.13.; *SD* = 0.93; *t* (155) = 8.52; *p* = 0.00 < 0.05) which is the highest-ranked to "Using BIM will enable me to accomplish my design more quickly" (mean = 3.11; *SD* = 0.86; *t* (155) = -5.67; *p* = 0.00 <0.05) which is the least ranked. To get the most significant experiences based on the mean score, a threshold of 3.5 was set with a reference to the *p*-value which should be less than 0.05 for each of the significant variables. Therefore,

only three (3) of these performance expectancy variables were considered significant because they were above the set 3.5 thresholds.

The mean score of the variables under "***Effort Expectancy***" ranges between 3.35 and 4.15. These variables ranged from "I do not have difficulty in explaining why using BIM may be beneficial*"* (mean = 4.15.; *SD* = 0.68; *t* (155) = 11.90; *p* = 0.00 < 0.05) which is the highest-ranked to "My client would love a BIM-enabled project" (mean = 3.35; *SD* = 1.30; *t* (155) = -1.42; *p* = 0.16 >0.05) which is the least ranked. To get the most significant experiences based on the mean score, a threshold of 3.5 was set with a reference to the *p*-value which should be less than 0.05 for each of the significant variables. Therefore, only four (4) of these effort expectancy variables were considered significant because they were above the set 3.5 thresholds.

The mean score of the variables under "***Social Influence***" ranges between 3.64 and 4.19. These variables ranged from "People who are important to me think that I should use BIM*"* (mean = 4.19.; *SD* = 1.06; *t* (155) = 8.16; *p* = 0.00 < 0.05) which is the highest-ranked to "People who are important to me(e.g colleague" (mean = 3.64; *SD* = 1.07; *t* (155) = 1.64; *p* = 0.10 >0.05) which is the least ranked. To get the most significant experiences based on the mean score, a threshold of 3.5 was set with a reference to the *p*-value which should be less than 0.05 for each of the significant variables. Therefore, all the five (5) variables of social influence were considered significant because they were above the set 3.5 thresholds.

The mean score of the variables under "***BehaviourIntention*** " ranges between 3.12 and 4.05. These variables ranged from "I intend to use BIM in future*"* (mean = 4.05.; *SD* = 0.83; *t* (155) = 8.34; *p* = 0.00 < 0.05) which is the highest-ranked to "I predict that I will use BIM in the future" (mean = 3.12; *SD* = 1.33; *t* (155) = -3.60; *p* = 0.0 <0.05) which is the least ranked. To get the most significant experiences based on the mean score, a

threshold of 3.5 was set with a reference to the *p*-value which should be less than 0.05 for each of the significant variables. Therefore, three (3) of this Behaviour Intention were considered significant because they were above the set 3.5 thresholds.

The mean score of the variables under "***Actual use***" ranges between 3.11 and 4.11. These Factors ranged from "I can use BIM to assess the sustainability of building*"* (mean = 4.11.; *SD* = 0.95; *t*(155) = 7.97; *p* = 0.00 < 0.05) which is the highest-ranked to "I can use BIM to extract the quantities for bill preparation" (mean = 3.11; *SD* = 0.86; *t* (155) = -5.67; *p* = 0.0 <0.05) which is the least ranked. To get the most significant experiences based on the mean score, a threshold of 3.5 was set with a reference to the *p*-value which should be less than 0.05 for each of the significant variables. Therefore, four (4) of this Actual use were considered significant because they were above the set 3.5 thresholds.

The mean score of the variables under "***Adoption of BIM*** " ranges between 3.28 and 4.13. These variables ranged from "Facility management*"* (mean = 4.13.; *SD* = 1.03; *t* (155) =7.59; *p* = 0.00 < 0.05) which is the highest-ranked to "Clash detection" (mean = 3.28; *SD* = 1.09; *t* (155) = -2.56; *p* = 0.01 <0.05) which is the least ranked. To get the most significant experiences based on the mean score, a threshold of 3.5 was set with a reference to the *p*-value which should be less than 0.05 for each of the significant variables. Therefore, six (6) of this Adoption of BIM were considered significant because they were above the set 3.5 thresholds.

The mean values for constructs in the conceptual model based on the UTAUT model including facilitating conditions, effort expectancy, performance expectancy, behaviour intention, actual use, adoption of BIM and social influence indicators are between 3.11 and 4.19 which is above average (around 62-84%). The descriptive statistics also

suggest that most of the respondents agree with the statements in the questionnaire as observed in the table.

Table 4.7: Variables Influencing the Intention-to-use BIM (UTAUT Construct)

S/N	UTAUT Constructs	MS	*SD*	t-value (μ = 3.5)	*df*	Sig. (2-tailed)	R
Facilitating Conditions							
FC5	My clients have an interest in the use of BIM	3.96	0.74	7.75	155	0.00	1
FC4	I have the required subscription for BIM packages	3.57	1.04	0.85	155	0.40	2
FC1	I have the resources necessary to use BIM	3.54	1.15	0.49	155	0.63	3
FC3	A specific person or group is available for assistance with difficulties concerning the use of BIM	3.47	1.08	-0.37	155	0.71	4
FC2	BIM is compatible with other systems that I use	3.40	1.22	-1.05	155	0.29	5
Performance Expectancy							
PE1	Using BIM is of benefit to me	4.13	0.93	8.52	155	0.00	1
PE4	Using BIM improves my performance in my job	4.03	0.73	9.09	155	0.00	2
PE3	Using BIM will increase my productivity	3.90	1.25	3.99	155	0.00	3
PE5	Using BIM will increase clients satisfaction	3.17	1.10	-3.78	155	0.00	4
PE2	Using BIM will enable me to accomplish my design more quickly	3.11	0.86	-5.67	155	0.00	5
Effort Expectancy							
EE4	I do not have difficulty in explaining why using BIM may be beneficial	4.15	0.68	11.90	155	0.00	1
EE3	I clearly understand how to use BIM	4.04	0.79	8.62	155	0.00	2
EE2	Learning to use BIM will be easy for me	4.00	0.87	7.16	155	0.00	3
EE1	It will be easy for me to become skillful at using BIM	3.99	0.88	6.98	155	0.00	4
EE5	My clients would love a BIM-enabled project	3.35	1.30	-1.42	155	0.16	5
Social Influence							
SI2	People who are important to me (e.g. family, friends) think that I should use BIM	4.19	1.06	8.16	155	0.00	1
SI4	My clients think I should use BIM for them	4.18	0.74	11.46	155	0.00	2
SI1	People who influence my behaviour think that I should use BIM	4.13	1.08	7.25	155	0.00	3
SI5	My clients feel BIM would increase	3.82	1.27	3.16	155	0.00	4

	their project social status						
SI3	People who are important to me (e.g. colleagues) think that I should use BIM	3.64	1.07	1.64	155	0.10	5

Table 4.7 Continued: Variables Influencing the Intention-to-use BIM (UTAUT Construct)

Behavioural Intention							
BI1	I intend to use BIM in the future	4.05	0.83	8.34	155	0.00	1
BI3	I plan to use BIM in the future	3.71	1.16	2.28	155	0.02	2
BI5	I plan to include BIM output as a key project document	3.56	1.02	0.70	155	0.48	3
BI4	I intend to execute a BIM-enabled project	3.33	1.17	-1.85	155	0.07	4
BI2	I predict that I will use BIM in the future	3.12	1.33	-3.60	155	0.00	5
Actual Use							
AU3	I can use BIM to assess the sustainability of buildings	4.11	0.95	7.97	155	0.00	1
AU2	I can use BIM to create the design for buildings	3.96	0.72	8.04	155	0.00	2
AU5	I can use BIM to track project progress	3.76	1.26	2.60	155	0.01	3
AU1	I can use BIM to easily find clashes in building designs	3.60	1.00	1.28	155	0.20	4
AU4	I can use BIM to extract the quantities for bill preparation	3.11	0.86	-5.67	155	0.00	5
Adoption of BIM							
AB8	Facility management	4.13	1.03	7.59	155	0.00	1
AB6	Cost management and quantity take-off	4.03	0.80	8.32	155	0.00	2
AB5	Construction planning and sequencing	4.01	0.78	8.23	155	0.00	3
AB3	Improved design visualization	3.97	0.89	6.63	155	0.00	4
AB1	Building design	3.94	0.84	6.54	155	0.00	5
AB4	Quality/Completeness checking	3.89	0.91	5.39	155	0.00	6
AB7	Coordination of construction documents	3.31	1.27	-1.89	155	0.06	7
AB2	Clash detection	3.28	1.09	-2.56	155	0.01	8

Notes:*SD* = Standard Deviation; R = Rank; Sig. = Level of significance; MS = Mean score of the Variables Influencing the Intention-to-use BIM (UTAUT Construct) where 5 = strongly agree; 4 = agree; 3 = neutral; 2 = disagree; 1 = strongly disagree. The higher the mean score the more severe the barrier; df = degrees of freedom, *Significant at the 95 per cent level ($p < 0.05$)

4.4 Structural Equation Modelling (SEM)

4.4.1 Measurement model

The measurement model is similar to indicators and items that measure the latent variables. It as well explains the properties of the observed variables. The measurement

model deals with the relationship between the latent and observable variables. The subsections (4.4.1.1 and 4.4.1.2) below explain the accuracy of the measurement model in terms of"Convergent Validity" and "Discriminant validity" (Hair *et al*., 2006).

4.4.1.1 convergent validity

Convergent validity describes the degree of association between the measurements of the same construct (Hulland, 1999). For Partial Least Square (PLS), the convergent validity of a measurement model is determined based on two values including (Fornell and Larcker, 1981):

- Cronbach's alpha (α) and composite reliability scores (ρc)
- The Average Variance Extracted (AVE)

The Cronbach's alpha can be described as a reliability measure used to evaluate how the items account for the one-dimensional construct (Aibinuand Al Lawati, 2010). As seen in Table 4.8, the Cronbach's alpha for the initial and final model after deleting some of the low loading variables is higher than 0.500. The lowest was 0.691 for the "Social Influence" construct in the initial model. However, for the final model, the lowest alpha value was 0.778 which connotes that variables representing the constructs are reliable.

Due to the limitations of Cronbach's alpha, Hair Jr *et al.*(2016) applied composite reliability scores (ρc) in a bid to address the shortcomings of Cronbach's alpha. There is no distinct definition for Cronbach's composite reliability scores. Thus, it shares the same definition as Cronbach's alpha. A previous study by Nunnallyand Bernstein, (1978) established that a ρc value of 0.700 is reasonable for the modest reliability of the composite. As shown in Table 4.8, none of the ρc values was less than 0.700. For the final model, the ρc ranges between 0.837 and 0.945 which is greater than 0.700 as recommended by (Nunnallyand Bernstein, 1978). The ρc values for the study constructs include the following; BIM Adoption (ρc = 0.857), Actual Use of BIM (ρc = 0.945),

Intention to Use BIM (ρc = 0.944), Critical Success Factors (ρc = 0.940), Effort Expectancy (ρc = 0.906), Facilitating Condition (ρc = 0.878), Performance Expectancy (ρc = 0.903), and Social Influence (ρc = 0.837).

The average extracted (*AVE*) is another measure of convergent validity that is considered in this study. Regarding the threshold of *AVE*, a value of 0.500 and above is recommended as observed in previous studies (Wong, 2013; Olanrewaju*et al*., 2022). Table 4.8 shows that all the constructs passed this requirement except BIM Adoption (*AVE* = 0.471). The other constructs have their *AVE* between 0.538 and 0.809. Nonetheless, FornellandLarcker (1981) stated that in the case where *AVE* is lower than 0.500 (50%) which is the recommended value but ρc is greater than 0.600, the convergentvalidity of the construct is still acceptable considering the case of "BIM Adoption (ρc = 0.857)".

Table 4.8 also shows the outer loading of the constructs which is denoted as "Loading". As part of the measurement model evaluation as shown in Figure 4.2 which highlights the initial and final model for this study, eighteen (AB2, BI2, CF1, CF10, CF13, CF14, CF16, CF17, CF18, CF19, CF20, CF21, CF28, CF6, CF7, CF8, PE5, and SI3) out of sixty-six items were removed from the analysis because of low factor loadings (< 0.400). A basic rule is to have loading above 0.700 (Hair Jr *et al.*, 2017). Nonetheless, a loading of 0.400 has been considered in previous studies in order to avoid less impact of the constructs removal on the overall reliability of the model (Sujitand Rajesh, 2016). Following this consideration, some constructs with loadings higher than 0.400 but less than 0.700 were retained. These constructs include; *BIM Adoption* (AB4, AB6, AB8), *Actual Use of BIM* (AU2), *Critical Success Factors* (CF11, CF12, CF15, CF2, CF22, CF3, CF9), *Facilitating Conditions* (FC5), *Performance Expectancy* (PE1), and *Social Influence* (SI5). Figure 4.2 shows the Final model with hidden sub-constructs to better

view the performance of the model compared to Figure 4.1 that have the construct parameters notclear.

A

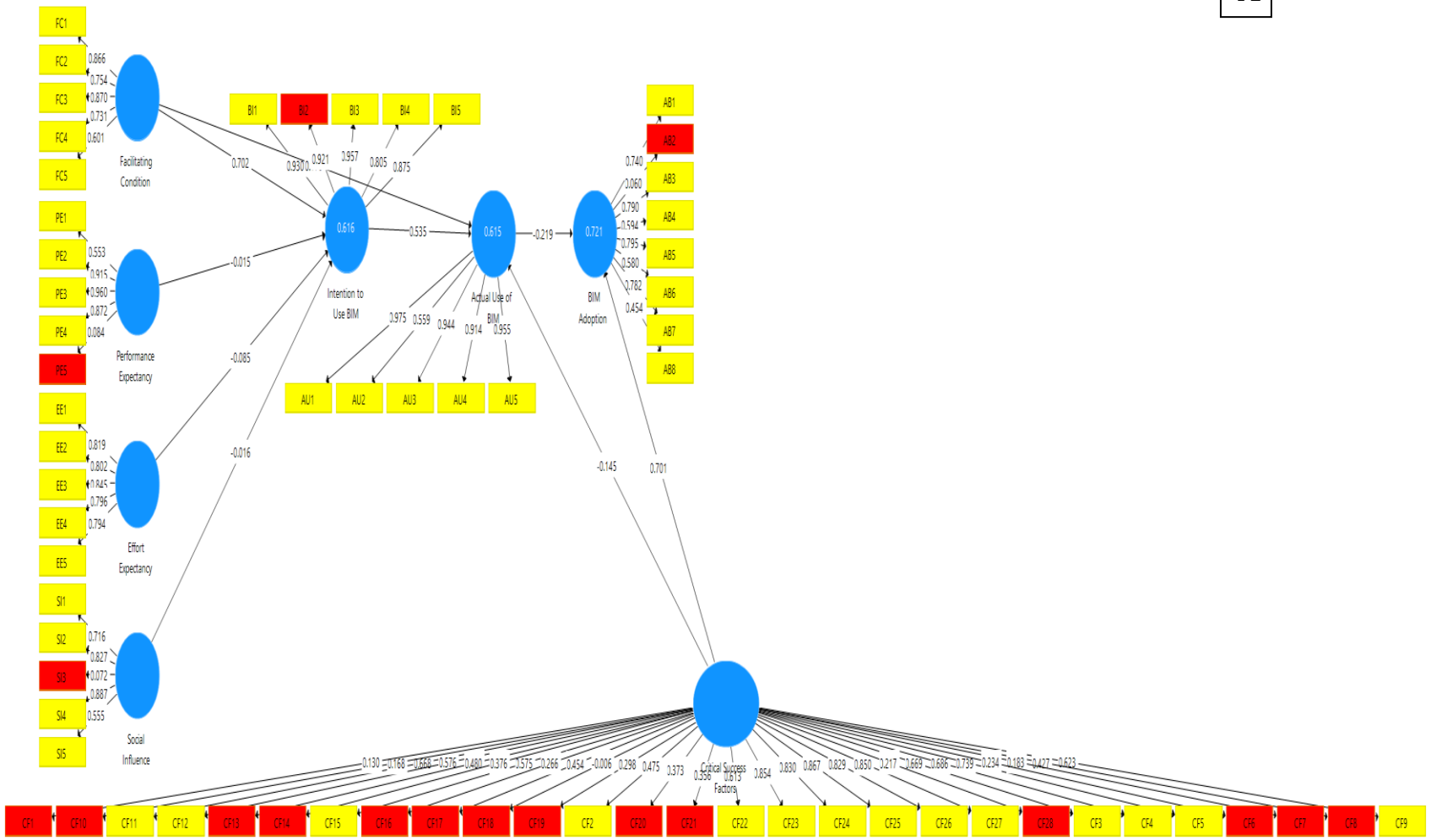

Figure 4.2: Initial (A)

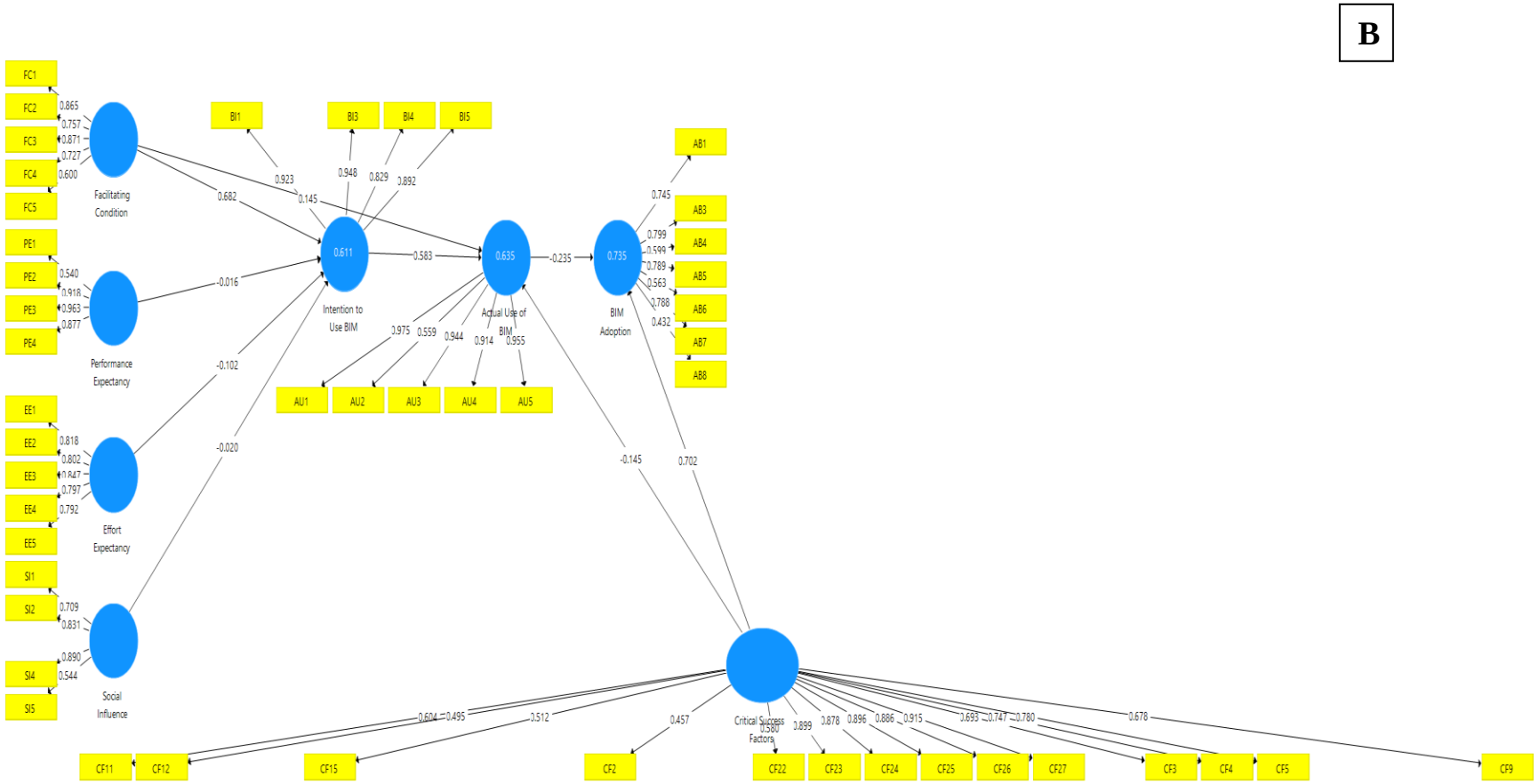

Figure 4.3: Final SEM (B) Model

Table 4.8: Convergent Validity

Constructs	Code	Initial					Final				
		Loading	**α**	***ρc***	**AVE**	**VIF**	**Loading**	**α**	***ρc***	**AVE**	**VIF**
BIM Adoption	AB1	0.740	0.769	0.831	0.414	2.166	0.745	0.810	0.857	0.471	2.165
	AB2	0.060				1.038	***Deleted**				***Deleted**
	AB3	0.790				1.891	0.799				1.891
	AB4	0.594				1.365	0.599				1.359
	AB5	0.795				2.183	0.789				2.183
	AB6	0.580				1.844	0.563				1.841
	AB7	0.782				2.408	0.788				2.408
	AB8	0.454				1.437	0.432				1.395
Actual Use of BIM	AU1	0.975	0.921	0.945	0.780	21.481	0.975	0.921	0.945	0.780	21.481
	AU2	0.559				1.260	0.559				1.260
	AU3	0.944				6.525	0.944				6.525
	AU4	0.914				4.814	0.914				4.814
	AU5	0.955				13.592	0.955				13.592
Intention to Use BIM	BI1	0.930	0.940	0.955	0.809	6.565	0.923	0.921	0.944	0.809	6.219
	BI2	0.921				5.435	***Deleted**				***Deleted**
	BI3	0.957				9.574	0.948				7.559
	BI4	0.805				2.301	0.829				2.301
	BI5	0.875				2.901	0.892				2.868
Critical Success Factors	CF1	0.130	0.898	0.907	0.304	1.204	***Deleted**	0.928	0.940	0.538	***Deleted**
	CF10	0.168				1.592	***Deleted**				***Deleted**
	CF11	0.668				2.961	0.604				2.022
	CF12	0.576				2.652	0.495				1.753
	CF13	0.480				2.722	***Deleted**				***Deleted**
	CF14	0.376				1.968	***Deleted**				***Deleted**
	CF15	0.575				1.891	0.512				1.536
	CF16	0.266				1.962	***Deleted**				***Deleted**
	CF17	0.454				1.926	***Deleted**				***Deleted**

Table 4.8 Continued: Convergent Validity

Constructs	Code	Initial					Final				
		Loading	α	ρc	AVE	VIF	Loading	α	ρc	AVE	VIF
Critical Success Factors	CF18	-0.006				1.641	***Deleted**				***Deleted**
	CF19	0.298				2.023	***Deleted**				***Deleted**
	CF2	0.475				1.896	0.457				1.215
	CF20	0.373				2.842	***Deleted**				***Deleted**
	CF21	0.356				2.008	***Deleted**				***Deleted**
	CF22	0.613				2.100	0.580				1.648
	CF23	0.854				11.598	0.899				9.945
	CF24	0.830				5.917	0.878				5.172
	CF25	0.867				8.540	0.896				6.961
	CF26	0.829				5.819	0.886				4.747
	CF27	0.850				10.734	0.915				9.131
	CF28	0.217				1.590	***Deleted**				***Deleted**
	CF3	0.669				2.687	0.693				2.298
	CF4	0.686				3.072	0.747				2.809
	CF5	0.739				3.062	0.780				2.578
	CF6	0.234				1.663	***Deleted**				***Deleted**
	CF7	0.183				1.470	***Deleted**				***Deleted**
	CF8	0.427				2.533	***Deleted**				***Deleted**
	CF9	0.623				2.147	0.678				1.964
Effort Expectancy	EE1	0.819	0.870	0.906	0.658	2.155	0.818	0.870	0.906	0.658	2.155
	EE2	0.802				1.866	0.802				1.866
	EE3	0.845				2.660	0.847				2.660
	EE4	0.796				2.163	0.797				2.163
	EE5	0.794				1.816	0.792				1.816
Facilitating Condition	FC1	0.866	0.825	0.878	0.594	2.378	0.865	0.825	0.878	0.594	2.378
	FC2	0.754				1.693	0.757				1.693
	FC3	0.870				2.473	0.871				2.473
	FC4	0.731				1.542	0.727				1.542
	FC5	0.601				1.314	0.600				1.314

Table 4.8 Continued: Convergent Validity

Performance Expectancy	PE1	0.553	0.744	0.841	0.566	1.252	0.540	0.846	0.903	0.708	1.193
	PE2	0.915				6.337	0.918				6.330
	PE3	0.960				9.750	0.963				9.749
	PE4	0.872				3.230	0.877				3.227
	PE5	0.084				1.053	***Deleted**				***Deleted**
Social Influence	SI1	0.716	0.691	0.776	0.459	2.082	0.709	0.778	0.837	0.570	2.077
	SI2	0.827				1.689	0.831				1.682
	SI3	0.072				1.020	***Deleted**				***Deleted**
	SI4	0.887				1.749	0.890				1.740
	SI5	0.555				1.816	0.544				1.811

Notes: α = Cronbach's Alpha, ρc = Composite Reliability, *AVE* = Average Variance Extracted

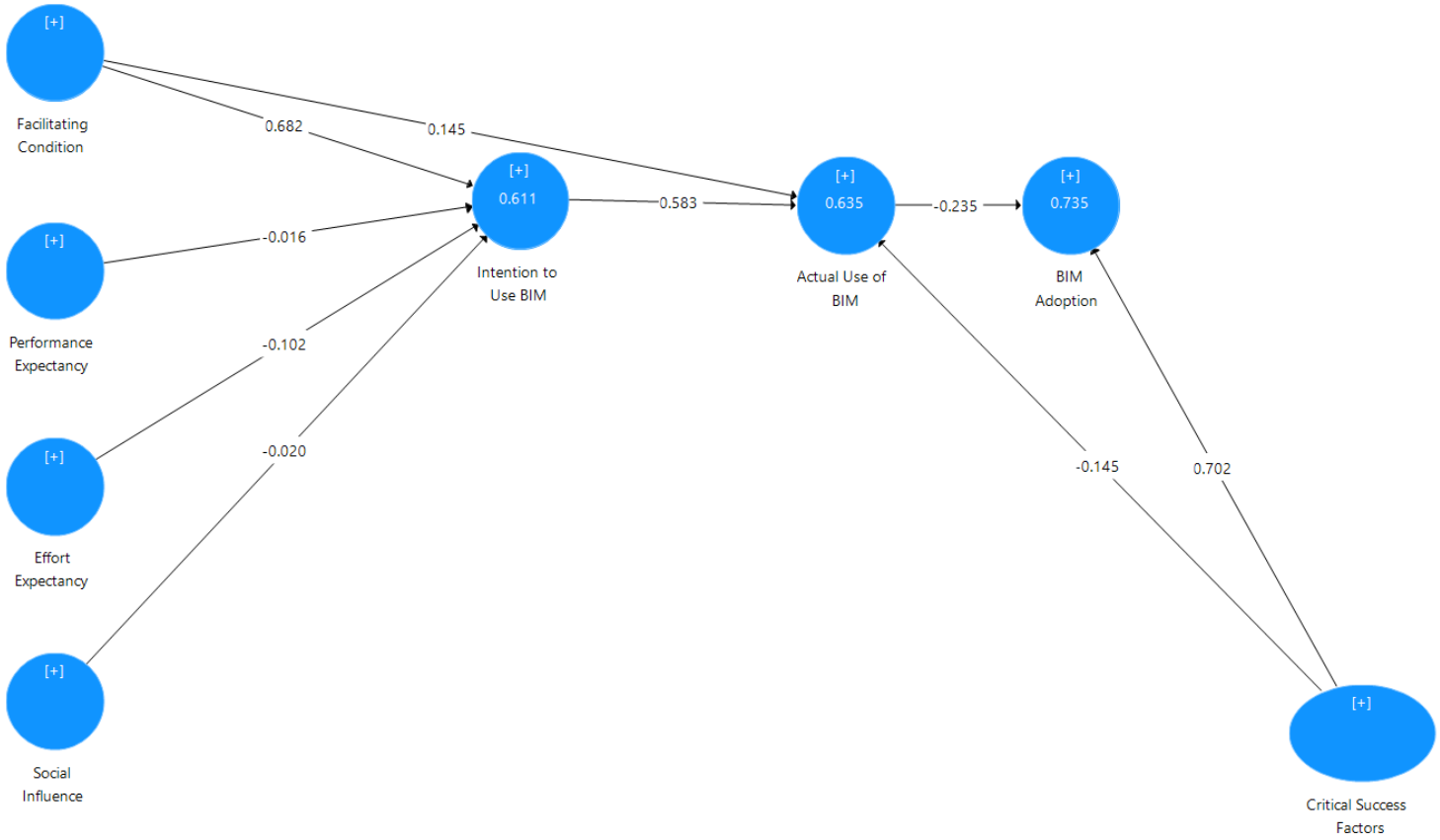

Figure 4.4: Simplified Final Model with Hidden Sub-Construct

4.4.1.2 discriminant validity

Discriminant validity is significant when a construct is different from other constructs based on the observed standards. Discriminant validity can be measured in three ways including:

- Fornell-Larckercriterion
- HTMT (Hetrotrait-Monotrait ratio of correlations) criterion
- Cross Loading criterion

Table 4.9 shows the result of the discriminant validity assessed by the Fornell-Larcker criterion. The table shows the relationship between the square root of *AVE* and the inter-construct correlation. The square root of *AVE* was higher than the inter-construct correlation for Actual Use of BIM, Effort Expectancy, Intention to Use BIM, Performance Expectancy, Social Influence.

Table 4.9: Fornell-Larcker Criterion

S/N	Constructs	1	2	3	4	5	6	7	8
1	Actual Use of BIM	**0.883**							
2	BIM Adoption	-0.633	**0.687**						
3	Critical Success Factors	-0.568	0.835	**0.734**					
4	Effort Expectancy	-0.644	0.943	0.814	**0.811**				
5	Facilitating Condition	0.690	-0.740	-0.635	-0.740	**0.771**			
6	Intention to Use BIM	0.778	-0.628	-0.569	-0.629	0.777	**0.899**		
7	Performance Expectancy	-0.455	0.559	0.500	0.593	-0.569	-0.478	**0.841**	
8	Social Influence	-0.413	0.590	0.455	0.602	-0.526	-0.451	0.644	**0.755**

Notes: Bolded numbers are the square root of *AVE*

Table 4.10 shows the results of the Heterotrait-Monotrait Ratio (HTMT) analysis. Henseler *et al.* (2015) further revealed through the use of Monte Carlo simulation that HTMT have higher specificity and sensitivity rates compared to Fornell-Larcker and cross-loading criterion. All the constructs have their correlations below the threshold of 0.900 as

recommended by Gold *et al.*(2001) and Henseler*et al*. (2015) except for the relationship between BIM Adoption and Effort Expectancy (1.091) with correlation above 0.900. Nonetheless, it is important to note some constructs that are very close to 0.900 such as BIM Adoption and Critical Success Factors (0.886), Effort Expectancy and Critical Success Factors (0.896), and BIM Adoption and Facilitating Condition (0.899). This implies that the HTMT criterion revealed that there is a problem of collinearity among the latent constructs (multicollinearity).

Table 4.10: Heterotrait-Monotrait Ratio (HTMT)

S/N	Constructs	1	2	3	4	5	6	7	8
1	Actual Use of BIM	-							
2	BIM Adoption	0.722	-						
3	Critical Success Factors	0.611	**0.886**	-					
4	Effort Expectancy	0.717	**1.091**	**0.896**	-				
5	Facilitating Condition	0.786	**0.899**	0.716	0.864	-			
6	Intention to Use BIM	0.835	0.707	0.618	0.692	0.867	-		
7	Performance Expectancy	0.504	0.694	0.566	0.697	0.671	0.544	-	
8	Social Influence	0.405	0.786	0.463	0.645	0.585	0.444	0.708	-

Notes: Bolded numbers are very close to 0.900 or ≥ 0.900

The third method used to assess the discriminant validity is the cross-loading criterion as shown in Table 4.11. The cross-loading criterion measures the loading of indicators on a given latent structure. It is based on the premise that the loading of the indicator should be higher than the loading by the row of the other constructs. As seen in Table 4.11, five of the sub-constructs have their loading below the row loading. These sub-constructs include; BIM Adoption (AB5, AB7, and AB8), Critical Success Factors (CF2), and Effort Expectancy (EE1).This suggests a moderate degree of one-dimensionality.

Table 4.11: Cross Loadings Criterion

Items	BIM Adoption	Actual Use of BIM	Intention to Use BIM	Critical Success Factors	Effort Expectancy	Facilitating Condition	Performance Expectancy	Social Influence
AB1	**0.745**	-0.427	-0.488	0.492	0.627	-0.522	0.392	0.309
AB3	**0.799**	-0.520	-0.491	0.925	0.776	-0.563	0.423	0.418
AB4	**0.599**	-0.380	-0.449	0.528	0.593	-0.553	0.382	0.315
AB5	**0.789**	-0.461	-0.439	0.587	0.797	-0.568	0.457	0.573
AB6	**0.563**	-0.315	-0.291	0.294	0.462	-0.374	0.365	0.461
AB7	**0.788**	-0.562	-0.515	0.622	0.755	-0.590	0.360	0.307
AB8	**0.432**	-0.295	-0.280	0.234	0.368	-0.323	0.361	0.704
AU1	-0.624	**0.975**	0.785	-0.575	-0.638	0.678	-0.462	-0.422
AU2	-0.430	**0.559**	0.439	-0.296	-0.384	0.424	-0.246	-0.210
AU3	-0.571	**0.944**	0.704	-0.520	-0.595	0.635	-0.412	-0.387
AU4	-0.530	**0.914**	0.671	-0.498	-0.556	0.610	-0.387	-0.353
AU5	-0.621	**0.955**	0.775	-0.568	-0.632	0.663	-0.462	-0.414
BI1	-0.658	0.717	**0.923**	-0.566	-0.648	0.755	-0.414	-0.460
BI3	-0.629	0.725	**0.948**	-0.566	-0.628	0.747	-0.443	-0.435
BI4	-0.411	0.546	**0.829**	-0.402	-0.409	0.573	-0.431	-0.389
BI5	-0.533	0.787	**0.892**	-0.494	-0.548	0.703	-0.439	-0.336
CF11	0.408	-0.291	-0.301	**0.604**	0.382	-0.236	0.243	0.249
CF12	0.398	-0.236	-0.336	**0.495**	0.380	-0.273	0.185	0.245
CF15	0.504	-0.369	-0.408	**0.512**	0.427	-0.354	0.154	0.229
CF2	0.484	-0.439	-0.351	**0.457**	0.482	-0.461	0.740	0.519
CF22	0.520	-0.483	-0.427	**0.580**	0.525	-0.538	0.304	0.276
CF23	0.772	-0.504	-0.499	**0.899**	0.788	-0.579	0.489	0.447
CF24	0.750	-0.452	-0.450	**0.878**	0.750	-0.594	0.406	0.395
CF25	0.735	-0.526	-0.474	**0.896**	0.723	-0.495	0.405	0.412
CF26	0.748	-0.478	-0.464	**0.886**	0.759	-0.514	0.413	0.433
CF27	0.737	-0.464	-0.484	**0.915**	0.745	-0.546	0.448	0.392
CF3	0.554	-0.360	-0.388	**0.693**	0.460	-0.431	0.266	0.243
CF4	0.603	-0.390	-0.348	**0.747**	0.618	-0.411	0.333	0.249
CF5	0.620	-0.359	-0.402	**0.780**	0.558	-0.461	0.343	0.268
CF9	0.513	-0.362	-0.454	**0.678**	0.484	-0.469	0.281	0.199
EE1	0.806	-0.518	-0.489	0.938	**0.818**	-0.592	0.452	0.448
EE2	0.737	-0.454	-0.528	0.637	**0.802**	-0.597	0.530	0.470
EE3	0.790	-0.505	-0.477	0.606	**0.847**	-0.591	0.476	0.588
EE4	0.711	-0.537	-0.503	0.480	**0.797**	-0.599	0.565	0.639
EE5	0.777	-0.592	-0.545	0.644	**0.792**	-0.618	0.382	0.313

Table 4.11 Continued: Cross Loadings Criterion

FC1	-0.630	0.614	0.770	-0.567	-0.664	**0.865**	-0.526	-0.417
FC2	-0.536	0.438	0.554	-0.469	-0.529	**0.757**	-0.403	-0.452
FC3	-0.640	0.652	0.674	-0.544	-0.672	**0.871**	-0.491	-0.486
FC4	-0.542	0.494	0.538	-0.500	-0.490	**0.727**	-0.469	-0.381
FC5	-0.497	0.414	0.381	-0.330	-0.459	**0.600**	-0.254	-0.269
PE1	0.361	-0.208	-0.295	0.331	0.400	-0.331	**0.540**	0.360
PE2	0.482	-0.366	-0.393	0.427	0.490	-0.516	**0.918**	0.590
PE3	0.525	-0.446	-0.466	0.459	0.557	-0.549	**0.963**	0.607
PE4	0.492	-0.464	-0.430	0.451	0.529	-0.489	**0.877**	0.572
SI1	0.428	-0.247	-0.242	0.212	0.351	-0.295	0.358	**0.709**
SI2	0.440	-0.308	-0.363	0.409	0.455	-0.414	0.676	**0.831**
SI4	0.570	-0.445	-0.478	0.458	0.632	-0.547	0.540	**0.890**
SI5	0.253	-0.065	-0.080	0.122	0.191	-0.151	0.210	**0.544**

4.4.2 Structural model (path analysis)

Path analysis can be described as a linear regression predictive tool used in construction management research. It is also commonly used to analyze complex relationships between variables or constructs simultaneously (Tabachnick *et al.*, 2007). The structural model is the second model evaluated after fitting the measurement model. It shows the relationship between the exogenous and endogenous variables (Hair*et al.*, 2006; Ho, 2006). The evaluation of the structural model depicts the significance of the hypothesized parameter estimates (Hair *et al*., 2006). This as well included validating the study hypotheses (H_1, H_2, H_3, H_4, H_5, H_6, H_7, H_8, andH_9) as shown in Table 4.12.

Table 4.12: List of Hypotheses and Relative Paths

Hypotheses	Path
H_1: Facilitating condition (FC) has a positive influence on construction professionals' behavioural intention (BI) to use BIM.	FC →BI
H_2: Performance expectancy (PE) can improve construction professionals' BI to use BIM.	PE → BI
H_3: Effort expectancy (EE) has a positive influence on construction professionals' BI to use BIM.	EE → BI
H_4: Social influence (SI) has a positive influence on construction professionals' BI to use BIM.	SI → BI
H_5: FC has a positive influence on construction professionals' actual use of BIM (AU).	FC → AU
H_6: BI can increase construction professionals' usage of BIM.	BI → AU
H_7: Critical success factors of intention-to-use BIM has a positive influence on construction professionals' actual use of BIM.	CSF → AU
H_8: The actual use of BIM by construction professionals can enhance BIM adoption.	AU → AB
H_9: The critical success factors of intention-to-use BIM can positively influence BIM adoption.	CSF → AB

According to the conceptual framework in this model, there are nine hypotheses to be tested. PLS-SEM was used to evaluate the research hypotheses shown in Table 4.12. Figures 4.4 and 4.5 show the related model to the nine hypotheses. In order to test the importance of the hypotheses, Bootstrapping technique was used to re-sample the original dataset randomly to generate a dataset of 5,000 at a 95% confidence interval (CI) which is usually the maximum number of random samples. Table 4.13 and Figure 4.5 shows the standardized path coefficients (β) and p-values, it revealed that not all the hypotheses were significant at $P< 0.05$.

Only five (5) out of the nine (9) research hypotheses were significant. **H_1** evaluates whether FC has a positive influence on BI. The result revealed that FC has a significant positive influence on BI (β= 0.682, SD = 0.114, t = 5.978, p = 0.000). Hence, **H_1** was accepted.

H_6evaluates whether BI has a significant impact on AU. The result revealed that BI has a significant impact on AU (β= 0.588, SD = 0.118, *t* = 4.988, *p* = 0.000). Hence, **H_6** was accepted.**H_7** evaluates whether CSF has a positive influence on AU. The result revealed that CSF has a significant negative influence on AU (β= -0.144, SD = 0.048, *t* = 2.981, *p* = 0.003). Hence, **H_7** was accepted.**H_8** evaluates whether AU has a significant impact on AB. The result revealed that AU has a significant impact on AB (β= -0.229, SD = 0.061, *t* = 3.756, *p* = 0.000). Hence, **H_8** was accepted.**H_9** evaluates whether CSF has a positive influence on AB. The result revealed that CSF has a significant positive influence on AB (β= 0.712, SD = 0.047, *t* = 15.176, *p* = 0.000). Hence, **H_9** was accepted.

The other hypotheses that were not significant include **H_2**, **H_3**, **H_4**, and **H_5**. This is because their p-value is > 0.05.

Table 4.13: List of Hypotheses, Mean, Standard Deviation, T-Values, P-Values and Confidence Interval for the Model

Path	Hypotheses	β	SD	*t*	*p*	CI	
						2.50%	97.50%
Facilitating Condition → Intention to Use BIM (FC →BI)	**H_1**	**0.682**	**0.114**	**5.978**	**0.000***	**0.464**	**0.905**
Performance Expectancy → Intention to Use BIM (PE → BI)	**H_2**	-0.017	0.058	0.288	0.773	-0.141	0.088
Effort Expectancy→ Intention to Use BIM (EE → BI)	**H_3**	-0.103	0.108	0.955	0.340	-0.317	0.105
Social Influence → Intention to Use BIM (SI → BI)	**H_4**	-0.018	0.045	0.408	0.683	-0.102	0.071
Facilitating Condition → Actual Use of BIM (FC → AU)	**H_5**	0.141	0.113	1.248	0.212	-0.046	0.390
Intention to Use BIM → Actual Use of BIM (BI → AU)	**H_6**	**0.588**	**0.118**	**4.988**	**0.000***	**0.328**	**0.781**
Critical Success Factors → Actual Use of BIM (CSF → AU)	**H_7**	**-0.144**	**0.048**	**2.981**	**0.003***	**-0.241**	**-0.050**
Actual Use of BIM → BIM Adoption (AU → AB)	**H_8**	**-0.229**	**0.061**	**3.756**	**0.000***	**-0.356**	**-0.116**
Critical Success Factors → BIM Adoption (CSF → AB)	**H_9**	**0.712**	**0.047**	**15.176**	**0.000***	**0.604**	**0.792**

Notes: β = Original Sample, M = Sample Mean, SD = Standard Deviation, *t* = T Statistics, *p* = P Values, CI = Confidence Interval, *Significant at $P< 0.05$

The hypotheses with bolded β, standard deviation (SD), T-statistics (*t*), p-values, and CI are the accepted hypotheses.

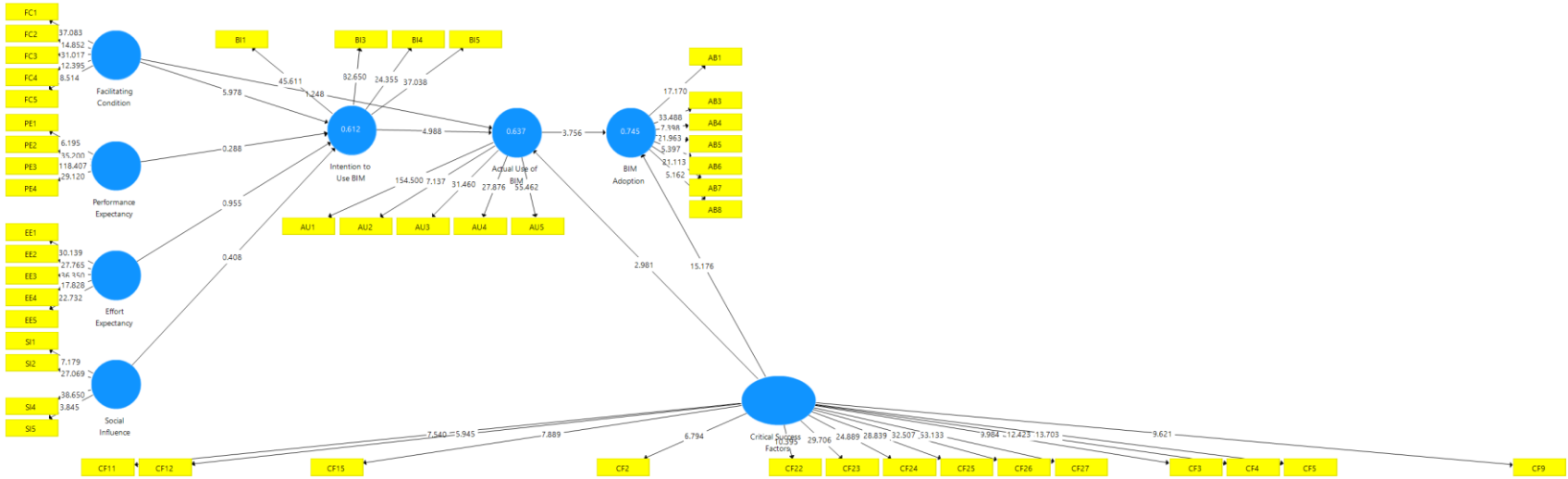

Figure 4.5: Path model (Bootstrapping Analysis)

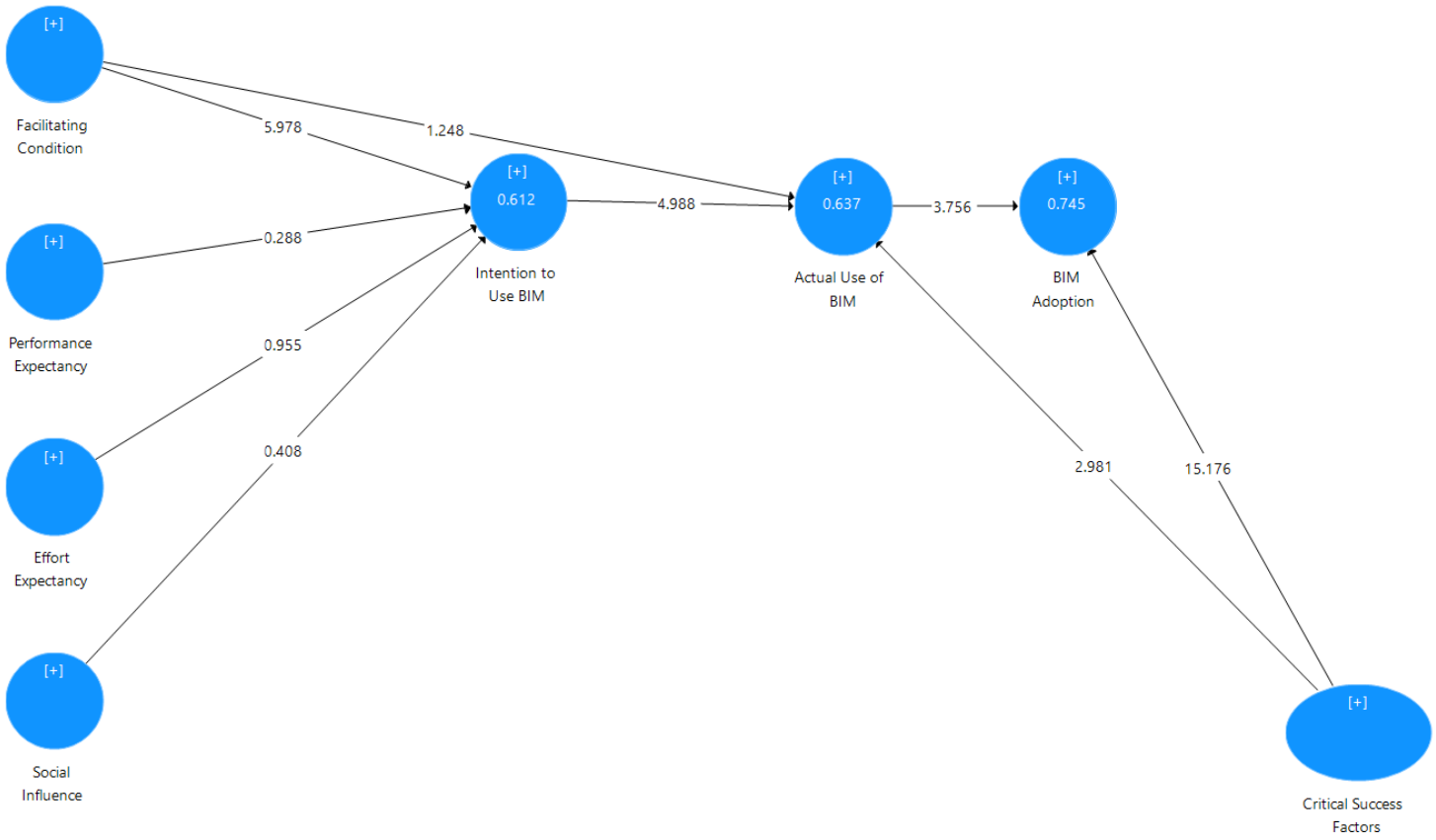

Figure 4.6: Simplified Path Model (Bootstrapping Analysis) with Hidden Sub-Constructs

4.4.2 Model predictive validation (model fit analysis)

4.4.2.1 explanatory power of the structural model (R^2)

The results presented in section 4.4.1 shows the reliability of the measurement model used in this study. The PLSalgorithm was used to calculate the squared multiple correlations of the dependent constructs (Actual Use of BIM, BIM Adoption, and Intention to Use BIM) in the model. R^2 depicts the amount of variance that can be explained by the independent constructs. The adjusted R^2 for "Actual Use of BIM", "BIM Adoption", and "Intention to Use BIM" is 0.628,0.731 and 0.601 respectively as shown in Table 4.14. With BIM Adoption as the main dependent variable of the model, an R^2 of 73.1% shows a strong effect of the other variables on BIM adoption.

Table 4.14: Results of the Coefficient of Determination (R^2)

Endogenous latent variable	R^2	R^2 Adjusted
Actual Use of BIM	0.635	0.628
BIM Adoption	0.735	0.731
Intention to Use BIM	0.611	0.601

4.4.2.2 predictive relevance Q^2 of structural model

Table 4.15 shows the results of the predictive relevance of the structural model. The blindfolding approach which was implemented in SMARTPLS was used to test the "*cross-validated redundancy*" measures for each dependent construct. Table 4.15 revealed that the Q^2 values of the three dependent variables (Actual Use of BIM = 0.488, BIM Adoption = 0.320, and Intention to Use BIM = 0.483) are greater than zero which means the independent constructs have predictive relevance for the dependent constructs (Hair *et al.*,2011).

Table 4.15: Results of Predictive Relevance (Q^2)

Endogenous Latent Variable	SSO	SSE	Q^2 (=1-SSE/SSO)
Actual Use of BIM	780	399.008	0.488
BIM Adoption	1092	742.478	0.320
Intention to Use BIM	624	322.314	0.483

4.5 Discussion of Results

The first research objective was to identify the critical success factors of intention-to-use BIM among construction professionals in the Nigerian construction industry. Mean item score was used to rank the critical success factors which were then grouped into four categories (*Organizational-related Factors*, *Process-related Factors*, *Customer-related Factors*, and *Educational Factors*) using factor analysis. The top ten critical success factors include Training and learning; Functionality; 3D Visualization, data sharing and BIM platform access; Ease of use and adoption; Standardization (product and process); Commitment; Availability of financial resources; Company' economic capabilities; Business process reengineering and coordination; and Awareness and experience level. Liu*et al.* (2021) explored the critical success factors to BIM in the Singapore context and found that the critical success factors to BIM adoption in the construction industry include; "BIM applications", "Organization's financial considerations", "Workflow transformation strategies", "Policies, capabilities, and support", "Teams" and "BIM functionalities". The findings from Liu *et al*. (2021) is in line with this current study because there is an agreement regarding financial factors, BIM applications and usage including policies to support its implementation. Papadonikolaki (2017) asserted that policies and standards are the lifelines for the adoption of innovative technologies. Similarly, Phang*et al.* (2020) developed a new model for identifying the critical success factors to BIM adoption based on precast

concrete manufacturers' perspectives. The top three critical success factors include government policies and support on BIM adoption, usage of BIM to maintain competitive advantage, and commitment from top management. Tsai *et al.* (2014) revealed the three top critical success factors to BIM adoption to include "support from top management", "design validation", and "functionality". Functionality ranked second in this current study and Tsai *et al*. (2014). This stresses the importance of functionality in BIM adoption. Furthermore, Ozorhon andKarahan (2017) explored the critical factors influencing BIM adoption in Turkey. The study revealed the top three critical success factors to BIM adoption as "effective leadership", "availability of qualified staff", and "availability of information and technology". The critical success factors were further classified into five groups (industry-related, human-related, project-related, resource-related factors, and policy-related) through the use of factor analysis. The industry, human, project and resource-related factors can be classified as organizational factors under the classification of this study. This depicts some level of agreement between the study and this current study based on the Nigerian construction industry. Sinoh *et al.* (2020) found that non-technical critical success factors ("communication", "leadership", and "culture") rank higher than the technical-related factors ("hardware availability" and "software knowledge"). Commitment at the firm level is another critical success factor for the effective implementation of BIM in the construction industry as identified by Sinoh*et al*. (2020). In addition, Awwad*et al*. (2020) studied the critical success factors influencing BIM level 2 implementation in small-medium enterprises (SMEs) and revealed fifteen (15) critical success factors that were classified into four groups namely; Human factors ("training of employees" and "people"), Organisational factors ("change management", "available resources", "top management support", "BIM awareness", "software compatibility", and "company vision/strategy"), Process factors

("BIM policy", "communication" and "collaboration"), External factors ("government support" and "client demand"). These findings from Sinoh*et al*. (2020) and Awwad*et al*. (2020) are in line with this current research findings.

The second research objective was to evaluate the variables that influence the intention-to-use BIM among construction professionals in Nigeria using the UTAUT constructs as a yardstick. Mean item score was used to rank the identified variables from the literature review that influence the intention-to-use BIM. The highly ranked variables in each of the constructs include; Facilitating Conditions ("My clients have an interest in the use of BIM"), Performance Expectancy ("Using BIM is of benefit to me"), Effort Expectancy ("I do not have difficulty in explaining why using BIM may be beneficial"), Social Influence ("People who are important to me (e.g. family, friends) think that I should use BIM"), Behavioural Intention ("I intend to use BIM in the future"), Actual Use ("I can use BIM to assess the sustainability of buildings"), and Adoption of BIM ("Facility management"). The variables used to represent the constructs are similar to that of Mahamadu*et al.* (2014).

The third research objective was to assess the relationship between intention-to-use BIM among construction professionals. Structural equation modelling (SEM) was used to explore the relationship between the variables identified in the second research objective. The results from the SEM revealed five significant hypotheses. The relationship between facilitating conditions (FC) and behavioural intention (BI) to use BIM; behavioural intention (BI) to use BIM and the actual use of BIM (AU); critical success factors (CSF) and the actual use of BIM (AU); actual use of BIM (AU) and BIM adoption (AB); and critical success factors (CSF) and BIM adoption (AB) were found to be significant. On the other side, the relationship between performance expectancy (PE) and behavioural intention (BI) to use BIM; Effort expectancy (EE) and

behavioural intention (BI) to use BIM; Social influence (SI) and behavioural intention (BI) to use BIM; and Facilitating conditions (FC) and actual use of BIM (AU) were found not to be significant. Howard *et al*. (2017) reported that SI has a strong influence on BI. In contrast, this study revealed that SI does not have a significant relationship with the behavioural intention (BI) to use BIM. In addition, Howard *et al*. (2017) revealed EE and FC as the two variables that influence BIM diffusion. The two significant constructs that influence BIM adoption as revealed by this study are AU and CSF. Consequently, AU is seen to be strongly influenced by BI and CSF while FC influence BI. Batarseh*et al.* (2019) emphasized the strong influence of FC as it necessitates the creation of a conducive environment for BIM to improve user's satisfaction which in turn improve the quality and cost of construction projects. Figure 4.6 shows the final research model after removing the variables with insignificant relationships.

4.6 Summary of Findings

BIM adoption from the perspective of technology adoption models has been seldom researched in the Nigerian construction industry. As a result, this study was aimed at assessing the construction professionals' behavioural intention on BIM adoption in Nigeria from the perspective of the UTAUT model. This study made the following findings which are summarized below:

1. The top ten (10) critical factors of the intention-to-use BIM include; The top ten critical success factors include Training and learning; Functionality; 3D Visualization, data sharing and BIM platform access; Ease of use and adoption; Standardization (product and process); Commitment; Availability of financial resources; Company' economic capabilities; Business process reengineering and coordination; and Awareness and experience level.

2. The categories of the critical success factors of the intention-to-use BIM include; organizational-related factors, process-related factors, customer-related factors, and educational factors.
3. Facilitating conditions (FC) has a significant positive influence on behavioural intention (BI)to use BIM.
4. Behavioural intention (BI) to use BIM has a significant impact on the actual use of BIM (AU).
5. Critical success factors (CSF) has a significant negative influence on the actual use of BIM (AU).
6. actual use of BIM (AU) has a significant impact on BIM adoption (AB).
7. Critical success factors (CSF) has a significant positive influence on BIM adoption (AB).
8. Performance expectancy (PE) cannot improve construction professionals' behavioural intention (BI) to use BIM.
9. Effort expectancy (EE) does not have a positive influence on construction professionals' behavioural intention (BI) to use BIM.
10. Social influence (SI) does not have a positive influence on construction professionals' behavioural intention (BI) to use BIM.
11. Facilitating conditions (FC)does not have a positive influence on construction professionals' actual use of BIM (AU).

4.6.1 Model for significant variables influencing BIM adoption

Figure 4.6 depicts the final model for significant variables influencing BIM adoption amongst construction professionals.

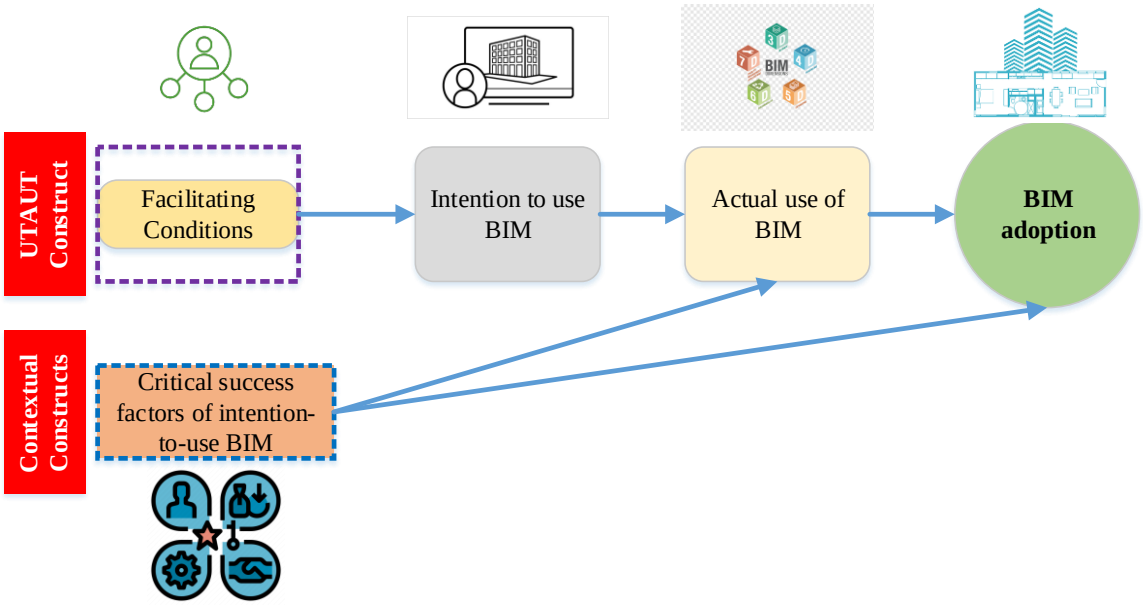

Figure 4.7: Final Model for Significant Variables Influencing BIM Adoption

The model reveals that facilitating condition (FC) has a significant positive influence on the behavioural intention (BI) to use BIM, while the remaining construct like performance expectancy (PE), effort expentancy (EE) and social influence (SI) does not have a positive influence on construction professionals' behavioural intention to use BIM.

On the other hand, behavioural intention (BI) to use BIM has a significant impact on the actual use of BIM (AU), critical success factors (CSF) has a significant negative influence on the actual use of BIM. AU of BIM has a signicant impact on BIm adoption and CSF has a significant positive influence on BIM adoption.

The model conforms with postulations from researches of Waluyani*et al.* (2018); Hewavitharana*et al.* (2021) have applied this model in various fields in understanding

the human perspective towards digitalization in the construction sector. Therefore, the model, when adopted will provide construction experts with perculiarities of the significant variables influencing BIM adoption.

The model was emanated from the Unified theory of Acceptance and Use of Technology (UTAUT) model figure 2.4. the UTAUT model is a model to provide explanation on the intention of the user in the use of information system and usage behavior (Attuquayefio, 2014; Berlak et al; 2021), it is a robust basis for the explanation of a wide range of technology diffusion issues (Wu et al; 2017). You may wish to recall that the aim of this study was to assess the construction professionals behavioural intention on BIM adoption in Nigeria from the perspective of the UTAUT model with the view to understanding that variables that hinders BIM adoption in Nigeria. To achieve this objective, the study nine (9) hypotheses were formulated and these hypotheses were based on the path relationship by the UTAUT model.

The first dependent variable, behavioural intention (BI) also known as “intention to use BIM” in this study predict facilitating conditions (FC), performance expectancy (PE), Effort Expectancy (EE) and social Influence (SI). Nonetheles, these variables have a strong influence on BI figure 2.5 (conceptual frame work). Having tested the study nine hypotheses, five (5) research hypotheses were found to be significant and the remaining four (4) were insignificant, this what led to the emanation of the above final model for significant variables influencing BIM adoption.

The model was emanated from the previous Unified Theory of Acceptance and Use of Technology (UTAUT) model that contains all the constructs like performance expectancy, Effort expectancy, Social Influence and facilitating conditions. PLS-SEM was used to test the nine (9) hypotheses that were formulated based on the UTAUT construct. PLS-SEM analysis revealed that out of the nine hypotheses, only five (5) (H1,

H6, H7, H8 and H9) were found to be significant while the rest (H2, H3, H4 and H5) were insignificant. Conclusively, the above model eliminated the construct with insiginificant variables and that depicts the major difference between the final model and the previous one.

CHAPTER FIVE

5.0 CONCLUSIONS, RECOMMENDATIONS AND AREAS FOR FUTURE STUDIES

5.1 INTRODUCTION

This is the last chapter of this thesis and it includes three sections; conclusion of the findings from the previous chapter, provision of recommendation based on the conclusion and suggestion of areas for further studies.

5.2 Conclusions

The use of BIM is central to effective construction project management in terms of cost, time and quality. This study provides information for construction industry stakeholders on how to improve the adoption of BIM in the Nigerian construction industry. A thorough understanding of the variables that influence BIM adoption is critical to adjusting the existing climate of BIM implementation. Given this, the study assessed the construction professionals' behavioural intention on BIM adoption in Nigeria from the perspective of the UTAUT model. Primary data were collected from one hundred and fifty-six (156) construction professionals in Abuja through the use of a questionnaire. The data collected was then analyzed using descriptive (charts and tables) and inferential statistics (*t*-test, factor analysis, and PLS-SEM) to generate logical deductions.

The study revealed the essential critical success factors of the intention-to-use BIM to include; Training and learning, Functionality, 3D Visualization, data sharing and BIM platform access, Ease of use and adoption, Standardization (product and process), Commitment, Availability of financial resources, Company' economic capabilities, Business process reengineering and coordination, and Awareness and experience level.

Proper consideration of these factors would enhance BIM uptake in the construction industry. One of the fundamental problems of BIM in Nigeria is the lack of standards and policies which has influenced its adoption despite the level of awareness.

The four significant variables influencing BIM adoption in the Nigerian construction industry is facilitating conditions, intention to use BIM, actual use of BIM, and critical success factors of the intention-to-use BIM. Stakeholders of the construction industry need to pay attention to facilitating conditions because of their strong influence on BIM adoption. The poor link between performance expectancy and BIM adoption suggested that professionals in the construction industry are yet to maximize the inherent benefits of BIM. The introduction of policies and standards would enable professionals to maximize these benefits.

Lastly, the findings of this study require the development of a national BIM standard and policies to control BIM practices in the construction industry. Nonetheless, a regular update of these policies and standards is required as BIM continues to evolve rapidly in many countries of the world.

5.3 Recommendations

This study proposes the following recommendations with the view to enhance the adoption of BIM in the Nigerian construction industry:

i. ***Collaboration between government and stakeholders of the construction industry***: government needs to collaborate with the stakeholders of the industry including professionals, clients, professional bodies, among others in order to actualize BIM implementation for construction projects.
ii. ***Formulation of appropriate policies and standards to embrace BIM adoption***: government and the concerned stakeholders need to work together to create BIM

policies and standards for the Nigerian construction industry so that BIM can be encouraged among construction professionals. This can include making BIM a mandatory requirement for building approval.

iii. ***Introduction of structured BIM curriculum to educate stakeholders***: education is one of the critical success factors of the intention-to-use BIM. As such, it requires adequate attention. This can include a collaboration between tertiary education boards (such as National Universities Commission [NUC]) to develop a detailed curriculum for BIM education in Nigeria.

iv. ***Creation of BIM awareness through advocacy programme***: professional bodies in the built environment in Nigeria should launch advocacy programmes to educate stakeholders regarding the potentials of BIM for the construction industry.

5.4 Contribution to Knowledge

This study has contributed substantially to the body of knowledge on BIM adoption in Nigeria from the perspective of the technology adoption model as follows:

i. The study revealed the critical success factors of the intention-to-use BIM among construction professionals.

ii. The study revealed the critical variables influencing BIM adoption in the Nigerian construction industry.

iii. The study extended the UTAUT model to include other constructs in order to measure BIM adoption.

5.5 Areas for Future Studies

This study has several limitations which future studies can build upon. Firstly, in terms of generalization, this study only considered one State out of thirty-six States in Nigeria

as such it would be difficult to generalize the findings of this study. Owing to this, future studies should consider including other States to improve the research generalization. Secondly, only the UTAUT model was considered for the conceptual framework of this study. Future studies could consider using other technology adoption theories such as the Technology Acceptance Model (TAM), Theory of Planned Behaviour (TPB), etc. Also, future studies should assess the performance of the final model of this research to determine its performance in accurately measuring BIM adoption.

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APPENDIX A

INTRODUCTION LETTER FOR QUESTIONNAIRE

Dear Sir / Madam,

IMPACT OF CONSTRUCTION PROFESSIONALS BEHAVIOURAL INTENTION ON BUILDING INFORMATION MODELING (BIM) ADOPTION IN ABUJA, NIGERIA

I am a graduate student currently working on the above research topic in partial fulfilment of the requirement of the award of Master's in Quantity Surveying at the Federal University of Technology, Minna.

This is to intimate you with a Master's research currently being undertaken in the Department of Quantity Surveying. And also, request your assistance in completing the attached questionnaire as a basis for the research. The study aims to assess the construction professionals' behavioural intention on BIM adoption in Nigeria from the perspective of the UTAUT model with the view to understanding the variables that influence BIM adoption in Nigeria.

The questionnaire has been designed such that it will not take you a long time to complete. We are sorry for the inconveniences imposed on you as we will like to assure you that any information that you provide would be treated as strictly confidential and used solely for research purposes. Your response to this questionnaire would be crucial to the research. Looking forward to your comments, and it would be appreciated if the research could be further discussed with you.

Thank you for your anticipated cooperation.

Yours Sincerely,

ISA, SULEIMAN
(MTECH/SET/2019/9772)

SECTION A: PERSONAL DATA

1. Name of organization location……
2. Position of the respondent in organization……...
3. Highest academic qualification (**please tick as appropriate**)

    a. Higher National Diploma ☐
    b. Bachelor Degree ☐
    c. Post Graduate Diploma ☐
    d. Master Degree ☐
    e. Doctorate Degree ☐

4. The profession of respondents **(please tick as appropriate)**
    a.
    b. Architect ☐
    c. Quantity Surveyor ☐
    d. Estate Surveyor ☐
    e. Builder ☐
    f. Engineer ☐
    g. Others ☐

5. The age group of respondents **(please tick as appropriate)**
    a.
    b. 21-30 ☐
    c. 31-40 ☐
    d. 41-50 ☐
    e. 50 above ☐

6. For how long have you been working in the Nigerian construction industry? **(please tick as appropriate)**

    a. Less than 5 years ☐
    b. 5-10 years ☐
    c. 10-15 years ☐
    d. 15-20 years ☐
    e. 20 years above ☐

7. Who are your main clients? (**please tick as appropriate**)

    a. Private ☐
    b. Government ☐

8. Size of the firm (**please tick as appropriate**)

    a. Small ☐
    b. Medium ☐
    c. Large ☐

SECTION B: BEHAVIOURAL INTENTION OF CONSTRUCTION PROFESSIONALS TOWARDS BIM

9. Rank the behavioural intention of construction professionals towards BIM using Likert Scale - *5 = Strongly Agree, 4 = Agree, 3 = not sure, 2 = Disagree and 1 = Strongly Disagree.* (**Tick as appropriate**)

S/N	Behavioural Factors	5	4	3	2	1
Facilitating conditions						
FC1	I have the resources necessary to use BIM					
FC2	BIM is compatible with other systems that I use					
FC3	A specific person or group is available for assistance with difficulties concerning the use of BIM					
FC4	I have the required subscription for BIM packages					
FC5	My clients have an interest in the use of BIM					
Performance expectancy						
PE1	Using BIM is of benefit to me					
PE2	Using BIM will enable me to accomplish my design more quickly					
PE3	Using BIM will increase my productivity					
PE4	Using BIM improves my performance in my job					
PE5	Using BIM will increase clients satisfaction					
Effort expectancy						
EE1	It will be easy for me to become skillful at using BIM					
EE2	Learning to use BIM will be easy for me					
EE3	I clearly understand how to use BIM					
EE4	I do not have difficulty in explaining why using BIM may be beneficial					
EE5	My clients would love a BIM-enabled project					
Social influence						
SI1	People who influence my behaviour think that I should use BIM					
SI2	People who are important to me (e.g. family, friends) think that I should use BIM					
SI3	People who are important to me (e.g. colleagues) think that I should use BIM					
SI4	My clients think I should use BIM for them					
SI5	My clients feel BIM would increase their project social status					
Intention						
BI1	I intend to use BIM in the future					
BI2	I predict that I will use BIM in the future					
BI3	I plan to use BIM in the future					

BI4	I intend to execute a BIM-enabled project					
BI5	I plan to include BIM output as a key project document					
Actual use						
AU1	I can use BIM to easily find clashes in building designs					
AU2	I can use BIM to create the design for buildings					
AU3	I can use BIM to assess the sustainability of buildings					
AU4	I can use BIM to extract the quantities for bill preparation					
AU5	I can use BIM to track project progress					
Adoption of BIM						
AB1	Building design					
AB2	Clash detection					
AB3	Improved design visualization					
AB4	Quality/Completeness checking					
AB5	Construction planning and sequencing					
AB6	Cost management and quantity take-off					
AB7	Coordination of construction documents					
AB8	Facility management					

SECTION C: CRITICAL SUCCESS FACTORS OF INTENTION-TO-USE BIM

10. Rank the critical success factors of intention-to-use BIM using Likert Scale - *5 = Strongly Agree, 4 = Agree, 3 = not sure, 2 = Disagree and 1 = Strongly Disagree.* (**Tick as appropriate**)

S/N	Critical Success Factors	5	4	3	2	1
CSF1	Interoperability and collaboration					
CSF2	Consumer and client requirement					
CSF3	Appropriate hardware and software					
CSF4	Integration and communication platforms					
CSF5	Culture and structure					
CSF6	Training and learning					
CSF7	Communication of BIM objectives/strategy					
CSF8	Top management support					
CSF9	Awareness and experience level					
CSF10	Organizational and staff BIM competencies					
CSF11	Policy					
CSF12	Business process reengineering and coordination					
CSF13	Standardization (Product and Process)					
CSF14	Ease of use and adoption					
CSF15	Project information coordination					
CSF16	BIM adoption strategies					
CSF17	Functionality					
CSF18	Management support					
CSF19	3D visualization, data sharing and BIM platform access					
CSF20	Client requirement and ownership					
CSF21	Commitment					
CSF22	Stakeholders involvement and information sharing					
CSF23	Regulatory agencies participation					
CSF24	Government's roles, support and legislation					
CSF25	Cost of development					
CSF26	Return on investment					
CSF27	Company' economic capabilities					
CSF28	Availability of financial resources					