Assessment of Building Information Modeling (BIM) Adoption in the Building Industry in Southwest Nigeria

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Certification

This is to certify that Akeem Akinola ALAJE with matriculation number LCU/PG/002683 carried out this research work titled "Adoption of Building Information Modeling (BIM) in the Building Industry: Southwest Nigeria" in the Department of Architecture, Faculty of Environmental Design and Management, Lead City University, Ibadan, Oyo state, for the award of Doctor of Philosophy Degree (PhD) in Architecture and that this has not been previously submitted.

…………………………… ……………………………..

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Head of the Department

Dedication

This research work is dedicated to the Father of our Lord Jesus Christ for His sustaining Grace over my life.

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Abstract

Building Information Modeling (BIM) is recognized globally as a technology that can enhance the efficiency of construction projects across design, construction, and maintenance. However, its adoption is lagging in many developing countries. Hence, this study examined BIM adoption in the Nigerian building industry with a view to enhance stakeholder collaboration. It adopted a cross-sectional survey in six cities of southwest Nigeria: Ikeja, Ibadan, Abeokuta, Akure, Ado-Ekiti, and Osogbo. The survey targeted four different building industry (Architectural, Structural Engineering, Quantity Surveying, and Building Contracting) firms. The questionnaire survey was conducted among the sampled 740 firms in the study area, with a return rate of 88.6%. The data obtained were analyzed using IBM-SPSS statistics for the descriptive, relative importance indexes, factor analysis, and Krustal-Wallis test. The result shows that the level of BIM adoption in the study area is low (32%) although the awareness level is high (72%). The respondents' firms use BIM-compliant software across the various stages of project execution but it is predominant at the design stage (69%), followed by the construction stage (19%), and then the maintenance/operation stage (12%). The Kruskal–Wallis tests revealed that except for one (provision of training by employers) out of the ten identified critical success factor CSF and seven (out of 32) identified benefits; there is no statistically significant difference in the perceptions of the four firm types. Reduce Rework in Construction (RII = 0.976), Improve Project Quality (RII = 0.962), and Minimize Errors and Mistakes (RII = 0.956) are found to be most three BIM benefits. The factor analysis result grouped the 39 identified barriers into five major factors: human-factors group (21.50%), management-factors group (19.88%), technological-factors group (15.81%), project-factors group (10.70%), and external-factors group (9.86%). The study concludes that although the knowledge of Nigerian building industry firms on the BIM concept is moderate, the level of adoption is relatively low. It is thus recommended that BIM CSFs be strengthened.

Keywords: Awareness, Adoption, Building Information Modelling (BIM), Nigerian building industry

Word Count: 300

Table of Contents

List of Tables

List of Figures

Chapter One

Introduction

1.1 Background to the Study

Building industry is one of the largest global industries but also one of the most disjointed systems. It is an industry characterized by a multidisciplinary group of people undertaking a unique project necessitating a high level of coordination [1]. To confront the coordination issues, advances in Information and Communication Technology (ICT) have been developed as a tool. This is to improve the industries' historically low productivity [2.] During the last three decades 1990 - 2020, the building industry has witnessed drastic improvements by adopting ICT. The latest and most promising ICT development is Building Information Modeling (BIM) [3]. The International Standard Organization (ISO) defines this platform as a "shared digital representation of physical and functional characteristics of any built object" capable of providing a reliable basis for decision-making. Depending on the context and purpose, different definitions of BIM can be found in the literature [4]. However, the concept of BIM has no generally accepted definition due to its evolving nature because new frontiers are creeping into the boundaries of its definition [5].

Various definition of BIM exists, each of them characterized by certain key points, which include "product", "process", "technology", "innovation", "and strategy" [6]. It was further explained that BIM involves the process, policies, and technological interactions to produce a methodology for managing the defects of building design and project data in digital format or virtual through the building life cycle [7]. Furthermore, it is believed that BIM connects all the professionals in the building industry, thus allowing information sharing within the project context (Figure 1 Appendix II). This practice promotes collaborative work among professionals such as architects, Construction contractors, surveyors, designers, and clients on a common information system [8]. Likewise, BIM can be described as a tool that enables the storage and reuse of information and domain knowledge throughout the lifecycle of the project [9]. To integrate and coordinate information and knowledge between different disciplines, BIM application is the main key to establishing a collaborative system in the building industry.

A BIM model comprises both the 3D geometry of each building element as well as a rich set of semantic information provided by attributes and relationships as shown in Figure 2 Appendix II [10,]. There are numerous applications of BIM, to mention but a few with design coordination, energy performance simulation, scheduling and quantity take-off, clash detection, and 3D visualization. Countries have been adopting BIM at different levels and with different purposes, having different experiences in terms of benefits, depending on the adoption level and possibly their challenges before the adoption. For example, the McGraw Hill Construction study discloses some substantial benefits of adopting BIM in Australia and New Zealand [8]. These include the reduction in rework, business reputation, effective management of construction time and cost as well as a reduction in errors and omissions [11].

The rationale behind BIM adoption varies from country to country; however, there are common goals among most countries. These include improving the industry's productivity and unifying its standardizations by changing its way of working [12]. BIM has now gone beyond a concept for building design and construction; it is fully into the infrastructural development process. Bentley has been developing highly sophisticated BIM tools for the engineering of infrastructural design and construction processes and it is generating acceptance throughout the construction and facility management sector. The same can be noticed with Autodesk in recent years [13].

Developed countries' BIM awareness has become nearly universal and its adoption and implementation are currently dynamic, though there is generated argument on its clarity in adoption level or stage [14]. In some countries, the introduction of the BIM methods is already at an advanced stage. Singapore, Finland, Korea, the USA, the UK, and Australia are among the early pioneers. In all these countries, the government and its subsidiary authorities play a key role in fostering the introduction and adoption of BIM. As far back as 2004, Singapore already made it obligatory to submit construction documents for public construction projects via an Internet platform to increase productivity in the industry by 25% [15].

Moreover, The United Kingdom (UK) government mandated the use of BIM on all publicly procured projects using 2016 as the deadline in a bid to reduce cost in the industry by 20%; this gravitated towards a 33% reduction in cost, subsequently 50% reduction in time, 50% reduction in greenhouse emission, 50% reduction in the trade gap, as targeted for the construction industry in the year 2025. This mandate has motivated BIM adoption in the UK construction industry [16]. In the United States, the US General Services Administration has pioneered the implementation of BIM on public projects leading to a proliferation of BIM adoption in the country. South Korea also mandated the use of BIM on projects over S$50 million for all public projects [16].

Similarly, countries such as Malaysia, Hong Kong, Canada, Australia, and China have embarked on various strategies for the proper implementation of Building Information

Modeling in their construction industries [17]. However, most developing countries except for Malaysia have been reportedly slow in the adoption and implementation of BIM [18]. The Nigerian building industry, like most developing countries, is regarded as a 'BIM infant industry'. This is despite the Nigerian building industry being the largest in West Africa. In Nigeria, it was found that the adoption of BIM is low while the awareness level is reasonable [19].

Moreover, in the Nigerian building industry, it was reported that despite the boom in construction, the implementation of BIM is low, especially among local contractors [20]. It was asserted that, despite the industry being bedeviled with myriads of problems such as cost overrun, time overrun, project abandonment, inefficiency, low productivity, and other associated problems, all attributed to the deficiency in communication and collaboration among the professionals in the building industry, building information modeling which has come to ameliorate these challenges as in other developed nations is yet to be embraced [21].

Furthermore, the lack of government support and awareness, lack of guidelines or strategies for implementation, and the high cost of implementation were identified as the cause of the slower rate of diffusion of BIM in developing nations, particularly Nigeria [22]. Therefore, the adoption of BIM has remained a challenging task in Nigeria due to the significant level of change management required the overcoming of individual resistance, and being comfortable with the existing traditional methods. Hence this research seeks to examine the current state of BIM adoption and optimization of its usage in the Nigerian building industry.

1.2. Statement of the Problem

The building industry is a unique one with its unique challenges. One of the challenges is the problem of fragmentation. The professional stakeholders operate in silos with a full monopoly of information. As a result, the sector suffers from inefficiencies and poor performance, project time overrun, cost overrun, risk/safety management issues, and building collapse. These challenges are mainly attributed to corruption, information and communication gaps, and faulty design [23]. It was further stated that, of all these causes of the challenges facing the building industry, communication and collaboration deficiencies are a principal factor [24].

Many researchers have investigated many approaches that can help to eliminate or bridge the information and communication gaps and as well strengthen the collaboration among building professionals [25, 26, 27]. Building Information Modelling was discovered to be the most effective and efficient because it encompasses and incorporates all other efforts [29]. Developed countries' BIM awareness has become nearly universal and its adoption and implementation are currently dynamic, though there is generated argument on its clarity in adoption level or stage [32, 33]. However, there remains a long way to go in most of the developing countries especially Nigeria [34]. It is imperative to note that the challenges of BIM implementation in Nigeria's building industry have led to the slow intake of BIM. Therefore, to overcome these barriers to effective BIM adoption in the Nigerian building industry, further studies are required to devise strategies for improving BIM implementation, examine its benefits, and analysis of BIM influencing factors [35].

Lastly. Prior research on BIM adoption in Nigeria has concentrated on the northern and central areas, with minimal attention to the southwest region [21, 39. 40]. It is against this background that this research is designed to examine the present status of BIM adoption, the factors influencing its adoption, and the strategies to enhance its uptake in the building industry in southwest Nigeria.

1.3 Aim and Objectives of the Study

This study aimed at examining the current state of BIM adoption in the Nigerian building industry with a view to improving design quality, construction accuracy, and overall project outcomes.

The objectives are to:

i. examine the common BIM software applications used by building firms in southwest Nigeria.

ii. assess the awareness level of BIM use across the building stages in the building industry in southwest Nigeria.

iii. identify the level of usage of BIM across the building stages in the building industry in southwest Nigeria.

iv. evaluate the factors that influence the adoption of BIM in the building industry in southwest Nigeria.

v. analyze the significant BIM benefits in the building industry in southwest Nigeria.

1.4 Research Questions

1. What are the common BIM software applications in the building industry in southwest Nigeria?
2. What is the level of awareness of the building industry firms of BIM uses across the building stages in southwest Nigeria?
3. To what extent is BIM deployment in the building industry in southwest Nigeria?
4. What are the factors that influence the adoption of BIM in the building industry in southwest Nigeria?
5. Are there significant benefits of BIM adoption in the building industry in southwest Nigeria?

1.5 Significance of the Study

This research arose from an increasing interest in minimizing the construction challenges in the building industry and the perceived effectiveness of BIM in achieving this goal and increasing productivity. A critical review of the limitations in relevant research that has been undertaken in the Nigerian building industry showed that there is a need for further research in this area. The literature reviews also showed that none has carried out a broad evaluation of the industry nor does the combination of the articles concerning the current status of the adoption of BIM. All the previous research concentrated on trying to assess BIM within a limited profession or location. Therefore, this research aimed at examining the current state of BIM adoption in the Soutwest Nigeria building industry with a view to fine-tuning collaboration among the building industry stakeholders. The following benefits are expected to be derived from this study:

1. Contributing to knowledge: The study filled the existing knowledge gap by providing empirical evidence on the current state of BIM adoption in the building industry of Southwest Nigeria. This research would contribute to the existing body of knowledge on BIM adoption, particularly in an understudied context like Nigeria.
2. Identifying barriers: The research identified the barriers and challenges faced by the building industry in Southwest Nigeria in adopting BIM technology. Understanding these barriers is crucial for policymakers, industry professionals, and researchers to develop appropriate strategies and interventions to overcome these challenges.
3. Promoting efficiency in construction: BIM technology has the potential to enhance the efficiency and productivity of construction projects. By assessing the level of BIM adoption in Southwest Nigeria, this research provided insights into the current efficiency levels and identified areas for improvement. This could result in cost and time savings for construction projects, leading to increased competitiveness and economic development in the region.
4. Supporting policy formulation: The findings of this research would guide policymakers and regulatory bodies in formulating policies and regulations related to BIM adoption in the building industry. By understanding the current state of BIM adoption, policymakers can develop targeted policies and incentives to encourage wider adoption of BIM technology, thereby promoting innovation and technological advancement in the construction sector.

5. Informing training and education programs: The study would provide insights into the skills and competencies required for successful BIM adoption in Southwest Nigeria. This information could be utilized to design training and education programs that cater to the specific needs of industry professionals and students, ensuring that they are adequately equipped with the necessary knowledge and skills to implement BIM technology effectively.

Overall, this research on Assessing BIM Adoption in the Building Industry in Southwest Nigeria has substantial significance in contributing to knowledge, identifying barriers, promoting efficiency, enhancing collaboration, supporting policy formulation, and informing training programs. Its findings would positively impact the building industry in Southwest Nigeria, leading to improved project outcomes and sustainable development in the region.

1.6 Scope of the Study

The scope of this study encompasses an in-depth assessment of the adoption of Building Information Modelling (BIM) in the building industry within Southwest Nigeria. This covers design, building/construction and operation/facility stage of project works.This study specifically focused and limted to the Southwest region of Nigeria, which includes states such as Lagos, Oyo, Ogun, Osun, Ondo, and Ekiti. This region is chosen due to its significant construction activities and economic importance.

1.7 Limitation of the Study

This study is limited to the Southwest region of Nigeria, which may not fully represent the broader context of Building Information Modelling (BIM) adoption across the entire country. Variations in regional practices, regulations, and cultural attitudes towards technology may influence the findings and limit the generalizability of the results to other areas of Nigeria or similar developing contexts. In addition, the research did not cover the adoption of BIM in other sectors such as civil engineering projects (e.g., roads, bridges) or other industries outside construction (e.g., manufacturing, oil and gas).

By clearly defining the scope and delimitation, this study aimed to provide a focused and manageable investigation into the adoption of BIM in the building industry in Southwest Nigeria, offering valuable insights and recommendations for enhancing BIM implementation in this region

1.8 Operational Definition of Terms

Building Information Modelling (BIM): A very broad term that describes the process of creating a digital model of a building or other asset (such as a bridge, highway, tunnel, and so on) using object-oriented information

BIM Collaboration Format (BCF): An open file format based on XML that allows adding comments to an Industry Foundation Classes BIM model.

BIM Execution Plan (BEP): A developing strategy prepared by suppliers that comprises a pre-contract BIM execution and then a post-contract BIM execution plan

BIM Maturity Levels: the levels of complexity and collaboration that building information modeling can take

BIM Protocol: A supplementary legal agreement that can be incorporated into professional services appointments, construction contracts, subcontracts and novation agreements.

BIM Task Group: Bringing together expertise to strengthen the public sector's BIM capability and provide the information the industry needs to meet the government's BIM requirement

BS 1192: Collaborative production of architectural, engineering, and construction information. Code of practice.

BS ISO 16739: Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries

BS EN ISO 19650: Organization and digitization of information about buildings and civil engineering works, including (BIM). Information management using modeling

CAD: Computer-Aided Design

CAFM: Computer-Aided Facility Management

Clash Rendition (CR): A rendition of a building information model specifically to avoid clashes in spatial co-ordination

Common Data Environment (CDE): The single source of information for the project, used to collect, manage and disseminate documentation, the graphical model and non-graphical data for the whole project team

Construction Operations Building Information Exchange (COBie): A non-proprietary multi-page, spreadsheet data format for the publication of a subset of building information models focused on delivering asset data rather that geometric information

Data: Information that has not been interpreted

Data Drops: Information of a particular format and level of detail issued to the client at pre-defined stages of a project. Also known as information exchange

Design Intent Model: The initial version of the project information model (PIM)

DGN: Micro Station and Intergraph file format

DWF: AutoCAD Design Web Format

DWG: AutoCAD file format

DXF: Interchange file format

Employer's Information Requirements (EIR): Set out the information required by the employer aligned to key decision points or project stages, enabling suppliers to produce an initial BIM execution plan from which their proposed approach, capability , and capacity can be evaluated

Federated Building Information Model: An assembly of distinct models to create a single, complete building information model of an asset

iBIM: Integrated Building Information Model, or Level 3 BIM

ICT: Information and communications technology

Industry Foundation Classes (IFC): A neutral, non-proprietary data format used to describe, exchange and share information

Information Delivery Manual (IDM): Specifies when certain types of information are required during the construction of a project or the operation of a built asset. Now known as the buildingSMART standard for processes

Information Exchange: Information of a particular format and level of detail issued to the client at pre-defined stages of a project. Also known as data drop

Information management process (IMP): Procedures implemented to manage the asset information model.

Level 0 BIM; Unmanaged computer aided design (CAD) including 2D drawings, and text with paper-based or electronic exchange of information but without common standards and processes

Level 1 BIM: Managed CAD, with the increasing introduction of spatial coordination, standardised structures and formats as it moves towards Level 2 BIM

Level 2 BIM: Managed 3D environment with data attached, but created in separate discipline-based models

Level 3 BIM: A single collaborative, online, project model with construction sequencing (4D), cost (5D) and project lifecycle information (6D). This is sometimes referred to as 'iBIM' (integrated BIM)

Standard Method and Procedure (SMP): Defines how Information is named, expressed and referenced.

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Chapter Two

Literature Review

2.1 Conceptual Review

2.1.1 Nigerian Building Industry

One of the largest industries in the world is the building industry. By 2020, it was projected to represent approximately 15% of the world's Gross Domestic Product (GDP), up from the current estimate of 6% [1]. With a difference of 3.81% over 30 years, the Nigerian building contribution to the GDP at the end of 2011 was only over 2%, which is statistically low compared to its record contribution of 5.8% in 1981 [2]. Despite the industry's erratic growth (both positive and negative), the Central Bank of Nigeria (CBN) estimated that it contributed 3.7% to Nigeria's GDP in 2018 [3]. In comparison to the 2011 growth rate of 1.99%, there has been significant growth. The building industry has yet to fully realize the potential of the present, despite the economic developments that are occurring today in almost every area [4].

Nigeria's GDP measurements have changed over the past several years, and it has been asserted that the building sector there provides 3 to 5% of the country's GDP [5]. However, regardless of a nation's level of economic growth, it is established that the building industry is a crucial part of every nation's economy [6]. Additionally, the building industry is one of the largest employers, accounting for around 10% of the labor force in most nations [7]. As a result, the building sector is one of the key sectors that contribute to the socioeconomic development of any nation, especially emerging economies.

Large-scale infrastructure and building projects in Nigeria are mostly commissioned by the federal and state public sectors. They occasionally use a design-and-build (turnkey project) contract but typically only do so when they are acquiring construction work [8]. In contrast, the public and private sectors are mostly responsible for the growth of the housing sector; depending on the area (state) in Nigeria, they alternately provide housing to the population [9]. Furthermore, statistics show that the majority of Nigeria's rental housing is provided by private landowners [10].

2.1.2. Major Construction Professionals in the Nigerian Building Industry

The industry is regarded as a skilled one that calls for a certain level of education, training, and experience [11]. In the building industry, there are many professionals. Architects, builders, engineers (civil, electrical, and mechanical), estate surveyors and valuers, land surveyors, quantity surveyors, and town planners are among the construction industry's active professionals in Nigeria [12]. Similar to this, the most important professionals in the building construction industry include architects, builders, engineers (civil, electrical, and mechanical), land surveyors, and quantity surveyors. The most active professionals, however, are architects, builders (as project managers or construction managers), engineers (civil, electrical, and mechanical), and quantity surveyors [13].

The most important players in the construction industry are the experts who work in the field, such as architects, contractors, structural and MEP engineers, and quantity surveyors. These professions are governed by several bodies and function independently of one another. Architect Registration Council of Nigeria (ARCON), Council of Registered Builders of Nigeria (CORBON), Council for the Regulation of Engineering in Nigeria (COREN), and

Quantity Surveyors Registration Board of Nigeria (QSRBN) are the certified professional organizations in charge of the registration and regulation of the professions and their activities.

However, coordination of these organizations and their extensive associations is not handled by a single governmental agency [14]. Therefore, this seems to be a setback for industrial cooperation. This implies the existence of a body tasked with coordinating the operations, procedures, and new common practices of the sector. Buildings require a large workforce, including individuals from many different industries and professions. Realizing a project requires a skilled project team from the point of view of project management. The professionals in construction who make up this team are those who were mentioned above. Since they are accountable for any damage that may occur within their specialized field during the construction, the necessary professionals in each part of the work, including design and construction, or both, should be closely examined [15].

The following professions are further discussed for the sake of this study and its context: architects, builders (in their capacities as project managers or construction managers), engineers (civil, electrical, and mechanical), and quantity surveyors.

2.1.2.1 Architect

Involved in the planning, design, and construction of a building is an architect, a professional in the building trades who has studied architecture. A building's concept and detailed design are produced by an architect after gathering information and translating a client's brief into account all pertinent requirements. Environmental, mental, anthropometric, and building codes are a few of these requirements. The expert is the client's initial point of contact, and he or she translates the needs and requirements of the user into a detailed drawing with specifications [16]. All of the building professionals collaborate with an architect's concept to develop their respective areas of work, making the architect the profession with the greatest range of skills. He is also regarded as a primary (lead) consultant during the design and execution phases [17]**.** A government entity, the Architects Registration Council of Nigeria, registers and regulates these professionals (ARCON). There is also a professional organization or association called "The Nigerian Institute of Architects (NIA)."

At both the design and construction stages, the architect is responsible for the following tasks: conceptual design based on the needs of the client, detailed design (in drawings and specs), planning, and building construction oversight [18]**.** Outside of being a construction project leader, the architect may also serve as a project manager on occasion.

2.1.2.2 Builder

A builder is also a building construction expert who is mostly involved in the building and maintenance stages of a building. A builder is a professional in building production management with academic training up to the bachelor's degree level [19]. The Institute of Building, which eventually became The Chartered Institute of Building, served as the initial development hub for this profession in Great Britain (CIOB). In the UK, people who work in this field are typically referred to as construction managers [20]. The Federal Republic of Nigeria's 1990 laws support the registration and regulation of the professions by the Council of Registered Builders of Nigeria (CORBON), a government entity (ACT CAP 40).

Additionally, establish "The Nigerian Institute of Building (NIOB)" as a professional organization or association.

The builder's responsibilities include ensuring that the construction project can be built, creating and ensuring the success of the project quality management plan, developing and ensuring the project health and safety plan is followed, and creating and ensuring the construction methodology is followed [21].

2.1.2.3 Engineers (Civil, Electrical and Mechanical)

Civil, electrical, and mechanical engineers constitute the engineering family that has dominated building design and construction. For all of the building's structural components, the civil engineer is in charge of analysis, design, and construction oversight. Roof trusses, foundations, slabs, beams, columns, and even geotechnical studies are some of these components. Roads, bridges, dams, and other forms of infrastructure development are all included in the scope of civil engineering, which is not just confined to building-related construction [22].

Engineers for services refer to both mechanical and electrical engineers combined. The design and oversight of the structure's electrically-related components fall under the purview of the electrical engineer, a qualified individual. The water and liquid waste disposal systems, on the other hand, are the purview of the mechanical engineer. The service engineers' duties extend beyond building-related construction; they also work on other infrastructure projects including power plants, water projects, factory construction, etc. [23].

The Council for the Regulation of Engineering in Nigeria (COREN) is an administrative organization that was created by military order 55 in the early 1970s and then modified by decree 27 in 1992. Under the "Engineers (Registration, etc.) Act, CAP E11 of 2004," the COREN is now governed. In addition to registering certified engineers to work as engineers in the Federal Republic of Nigeria, COREN is also in charge of registering and overseeing engineering firms operating in the nation. Nigerian Society of Engineers (NSE) is the name of the professional association for engineers, and the Nigerian Institute of Civil Engineers (NICE), Nigerian Institute of Electrical & Electronic Engineers (NIE), and Nigerian Institute of Mechanical Engineers are the organizations for engineers on an individual basis (NIME).

2.1.2.4 Quantity Surveyor (QS)

Britain was a pioneer in the field of quantity surveying. The quantity surveyor (QS) is a member of the construction sector who has completed quantity surveying coursework. A quantity surveyor is an expert who prepares the quantities and costs of proposed building works [24]. He also assures the efficient use of financial resources and cost control in the project's [25]. Every component of the work's cost implications and variations' consequences can be developed by the quantity surveyor [26]. The government organization in charge of registering professionals engaged in quantity surveying work in Nigeria is known as the Quantity Surveyors Registration Board of Nigeria (QSRBN).

From a project's early planning stages on, the QS plays a variety of functions. Cost estimation for materials, labor costs, a schedule of building materials, value engineering, cost planning, cash flow payment, cost-benefit analysis, creating a bill of quantities, work variation and cost performance, on-site materials, valuation for payments, and lifecycle costing are all among the roles that fall under the purview of quality assurance [27].

2.1.3 Challenges in the Nigerian Building Industry

The most prevalent and important difficulties facing the Nigerian construction sector include fragmentation, underperformance, time and cost overruns, conflicts, and building collapse. For more than ten years, these difficulties have remained. A terrible circumstance that instills terror in the public is the building collapse [28]. Numerous problems, such as ineffective cooperation, subpar or unsupervised construction, and flawed structural design, were cited as the root causes of this threat [29]. For instance, a study collated data for the ten years (2000 to 2010) of building collapses in Lagos State alone, and discovered that out of the 54 fallen buildings, 37 were the result of associated structural problems [30]. Even so, not much has been done to address these issues and the harm they pose [31].

Due to poor communication among the players in the construction sector, effective delivery of a construction project in Nigeria (on time and within budget) is becoming unfeasible. Time overrun is another key result of poor or ineffective communication in the sector [32]. Most construction projects in Nigeria are delivered late (behind time), with rework, and at a cost that is higher than what was budgeted for [33].

Moreover, In-situ or on-site production reduces quality and generates more waste during the construction phase. Working with full materials on-site was found to be one of the primary causes of waste; the main causes include offcuts, oversupply, and inadequate recycling [34]. A study provided evidence of the efficiency and speed with which prefabricated components can be used in home construction. However, complaints about exorbitant costs were made right away because of how expensive the machinery was. Large amounts of waste are produced each year by construction and demolition, with this category accounting for around 30% of waste creation [35]. Contrarily, it was reported that offsite construction in Nigeria is still in its infancy and that the bulk of Small & Medium Enterprises (SMEs) are not at all embracing contemporary construction techniques [36].

The business climate in Nigeria is a contributing factor to some of the industry's difficulties. A thorough analysis of the Nigerian construction market indicates significant flaws and dangers, including rampant corruption, lax intellectual property protection, and a reliance on the government for big projects. Additionally, the sector experienced a structural issue that is thought to be one of its key barriers to success [37]. The industry's structural difficulties may be the root of its fragmented structure, which results in poor information exchange and communication as well as a lack of trust and collaboration [38].

Building collapse, subpar projects, project delays, and cost overruns are, in short, the industry's major ongoing difficulties in Nigeria. Fragmented teamwork, inadequate information generation, transmission, and management are blamed for these difficulties [39]. As a result, the sector needs a better workflow that would promote information management and teamwork.

2.1.4 Efforts to Improve Productivity in the Building Industry

Many researchers have investigated many approaches that can help to eliminate or bridge the information and communication gaps and as well strengthen collaboration among the AEC professionals resulting into improved productivity [40, 41, 42]. It was also revealed that there have been emerging paradigms and technologies (e.g. lean construction, Building Information Modelling, Automation, Artificial Intelligence, etc.) over the years aimed at combating the myriad challenges of the industry and thereby improving the outputs and achieving value for money [43]. The phenomenon of low productivity in the construction industry is well recognized and a number of management systems and techniques were developed to improve the overall productivity of the construction industry. Some of these efforts are briefly introduced in the following sub-sections [44, 45].

2.1.4.1 Lean Construction

Lean construction is a management strategy that emphasizes value-adding activities while minimizing or eliminating unproductive work or activities [46]. The Toyota manufacturing system, which promotes concurrent and continuous development of the construction processes with minimal cost and maximum value, is one example of an industry that provided inspiration for the ideas of lean construction [47]. Lean construction's fundamental tenet is to cut back on non-value-adding tasks like waiting for permissions, for materials to arrive, etc. that don't immediately increase the productivity of the building process. Lean construction can significantly increase production by reducing labor hours and time waste, as demonstrated by a number of writers [48, 49, 50]. However, this is a management style that necessitates partnering and strategic collaborations among construction stakeholders, which is challenging to implement in a standard project context.

2.1.4.2 Pull Flow or Pull Construction

Pull construction is a different application of the lean construction philosophy that promotes using the least amount of time possible for building component production and detailing to reduce rework and last-minute adjustments [51]. This works well because the precise specifications and requirements for installations and equipment are sometimes unknown until the very end of the project. Pull construction technique advises delaying shop drawings and fabrication to the very last minute in order to prevent delays or rework from any design changes. As a result, shop drawings and detailing are only completed once, reducing non-value-adding activities and rework time waste [52].

2.1.4.3 Last Planner System

The last planner is the person or group who decides the specifics of any activity in the shortest amount of time feasible. They have the biggest influence over productivity at any unit level, and this is crucial for appropriate planning of successful and efficient operations [53]. Last planner system, rather than only planning of plans, it is suggested that the final link in the chain be given scheduling authority. Traditional construction schedules are created to account for operations that must be completed three to five weeks in advance, but the actual focus is typically on "what should be done" rather than adhering to the timeline. The most recent planning system enables the on-site planner to streamline the procedure by assessing tasks and their assembly by the project's overall project plan, ensuring that tasks and assignments are completed in the most productive manner possible [54].

2.1.4.4 Just-in-Time (JIT)

JIT is a further approach that originated from the Toyota Production System philosophy and is frequently used in conjunction with lean construction methods to decrease waste and increase productivity [55, 56]. The JIT strategy is especially helpful for projects with constrained space or tight deadlines, such as skyscraper or city center projects, where it is impossible to store materials on site before they are required for production. JIT concepts have been widely accepted and successfully applied in the manufacturing sector [57].

Moreover, they are also being tested in the construction sector to reduce the processing and storing of equipment and forces planning of labor and material coordination. JIT allows for "mass customization" by focusing on the most cost-effective way to make the final product rather than making each component. This simply entails just ordering from suppliers what is required on-site rather than having materials or equipment dumped on-site [58]. Although the JIT philosophy has been strongly supported as being advantageous to the construction industry, its implementation has not been very successful due to the necessity of logistic planning and computerized control systems, which are challenging to achieve in the environment of a construction site [59].

2.1.4.5 Total Quality Management (TQM)

TQM is yet another well-known production control and management method that advocates for the development of standard operating procedures and adherence to set specifications to optimize project procedures for better and more productive results. TQM systems have helped to boost efficiency in the manufacturing industry, but their usage in construction is still limited due to dynamic site conditions and transitory project settings [60]. The ISO (International Organization for Standardization) 9000 family is a quality assurance system that implements a quality management process before work begins, detecting and correcting problems before they reach catastrophic proportions. Large construction organizations typically hold ISO 9000 certification and have standardized work processes, manuals, operating procedures, and other instructions. By making specifications clearer and specifying the best way to get the desired outputs, increases productivity and cuts down on rework. Another TQM application known as Six Sigma can decrease waste by adjusting standard operating procedures and management practices. Because of the significant paperwork required and the ubiquitous nature of construction activity, construction and design firms frequently struggle to completely apply this approach.

2.1.4.6 Prefabrication

The productivity management strategies previously mentioned make it clear that uncontrolled dynamic site conditions and the workplace environment are the main obstacles to productivity improvement in the construction sector. These conditions make it difficult to directly apply productivity improvement strategies, which are typically created for fixed working conditions, like in the manufacturing sector. Therefore, by shifting as much of the building workload to factories where controlled conditions may be applied for greater productivity, construction researchers have continuously backed the idea of prefabrication [61]. When working in controlled circumstances, prefabrication of construction experts can apply a variety of productivity-improving strategies to reach the needed cost and quality.

It was noted that, using materials of a standard size improves productivity because it gives workers a sense of consistency and makes it easier to organize materials quickly and efficiently [62]. Prefabricated parts can be easily put together on-site, saving a great deal of time and effort that would otherwise be needed for submittals, design revisions, and approvals for shop drawings and other documents. Prefabrication, however, still necessitates precise and accurate information to begin the manufacturing process, which is challenging with typical 2D CAD because specific measurements aren't known until very late in project [63].

For instance, measurements of the site's current circumstances must be taken before MEP (mechanical, electrical, and plumbing) system details can be created. These measurements are then compared to shop drawings and filed dimensions for confirmation. Prefabrication can significantly increase construction productivity, but it necessitates accurate information upfront in the design stage, which is challenging with conventional CAD systems. Building Information Models can provide this more accurate and integrated information [64].

2.1.5 BIM Concept and Its Evolution

The introduction of BIM has shown strong potential to deliver significant productivity improvements throughout the life cycle of construction projects as it compasses all other efforts aforementioned, [65]. The development of technology has been hailed as a significant turning point for the construction industry, reshaping how work is done on construction projects in the built environment [66]. After sketch pad, created by Ivan Sutherland in 1962, initially popularized computer-aided design (CAD) in the construction sector, Autodesk followed suit with the development of a 2D system called AutoCAD that had a variety of capabilities and was continually enhanced with new platform features [67].

Later, as a technological advancement to address some issues with 2D CAD, 3D CAD appeared, much to the satisfaction of design firms and architects [68]. It was from this CAD platform that BIM developed, which included intelligent modeling [69]. Humans have a natural drive to improve upon existing technology, and problems with the use of 2D and 3D CAD systems prompted the search for a solution, which led to the development of BIM. Since Plan, Elevations, and Sections cannot interrelate automatically and CAD drawings are fragmented, it was once thought that these features rendered CAD drawings incapable of intelligence [70]. The same study has also criticized CAD drawings for constructability and communication problems, the difficulty for unskilled clients to grasp the CAD drawings, and the large number of drawings created during the building's lifespan upon revision of any component or part [71].

Major attempts were made to digitize the paper-based communication that existed in architecture, engineering and construction, which gave rise to the BIM concept. Architecture Engineering and construction (AEC) industry in the pre-1960 era from the period of its inception of use, it has been enriched with more capabilities, and this is denoted using the various dimensions of BIM with the dimensions ranging from 3D to 7D and nD as more capabilities will be incorporated [72]. Additionally, the construction and operation stages of the building process, including estimation (5D), life cycle management (7D), sustainability (6D), and others, have been added to the scope of coverage of BIM use, which was previously limited to the design stage only (Visualization Properties; 3D) [73]. BIM is now fully integrated into the process of developing infrastructure rather than only being a concept for building design and construction [74].

2.1.5.1 BIM Definitions

The literature review indicated that BIM has been described in a variety of ways, and its comprehension varies among industry professionals. BIM is described and presented as technology, a process, or a combination of both in a new approach to cause a paradigm shift in the way the construction industry works. A Building Information Model is essentially a 3D representation of a building's physical and functional attributes throughout its life cycle. A window of a specific material and dimension, for instance, is digitally housed in a wall of a certain material and dimensions according to parametric rules in a building information model. Any change in a building's components is immediately synchronized to all associated views of the digital model, which may be used as a knowledge resource to extract different perspectives, reports, and trustworthy data for a building's functional analysis.

The development of the use of technology to digitally simulate the design, construction, and operation of a facility from which different views of data suitable for various users can be extracted and used for decision-making that can enhance the process of overall project delivery is how BIM is defined by [75]. A third official definition of BIM is as follows: "Building Information Model is a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle " [76].

An intelligent digital assembly of building components with embedded knowledge of parametric object attributes and characteristics is how a building information model is created. It was also reasoned that, BIM is a process, tool, or product that creates intelligent digital models linked to other project management tools (such as schedule, BOQ, and cost estimate) that enable design optimization, constructability, and information sharing for all stakeholders for a better project outcome [77]. Many authors who describe BIM as being much more than just a technology for digital representation of buildings support the process view of the technology.

Furthermore, BIM is a collection of interconnected procedures, technology, and rules that together produce a new approach to managing the planning, execution, and maintenance of construction projects over the course of their entire lifecycle [78]. It's also claimed that BIM is an IT-enabled strategy for managing digital information in the construction sector. Moreover, BIM is also defined as the application of all relevant information and communication technologies (ICT) that are required to streamline and facilitate all processes involved in creating a better and safer environment [79]. BIM has been referred to most recently by writers as a technology-driven approach to develop information-rich, intelligent models that support life cycle information management for built environment projects [80, 81. 82,].

According to a review of the BIM definition, the software companies that are developing the technology and programs needed for the industry's adoption of BIM are in favor of the "BIM as a technology" viewpoint [83]. In contrast, the "BIM as a process or activity" perspective is supported by professional organizations in the sector, which are the primary forces behind reengineering industry methods to support and embrace BIM enabled working[84], [85] . Academics engaged in the study, advancement, and industry acceptance of BIM theory also characterize "BIM as a system, as a holistic approach, and as a cooperation technique." The Table 2.1 presents some illustrations of these points of view.

Table 2.1: Different perspectives on BIM definitions from literature review

	Categories (product vendors, industry and academia)	Definitions
Product vendors	Asta Power Project (2018)	The Industry Foundation Classes (IFC) data model is an open, international and standardised specification for Building Information Modelling (BIM) data that is exchanged and shared among software applications used by the various participants in a building, construction or facilities management project.
	Autodesk (2002, 2014)	BIM is use of information technology
	Graphisoft (2014)	BIM is a technology that offers users simulation, collaboration, auditability and maintainability.
	Bentley & Workman, (2003) and Bentley, 2011)	BIM is a new way of approaching the design and documenting of building projects
Professional institutes and the industry	VVT Finland (Bazjanac & Kiviniemi, 2007)	BIM is strategic thinking, tactical thinking and operational thinking supported by the use of technology.
	AGC (2006)	BIM is an activity of creating data-rich, object oriented, smart and parametric digital representation of a facility.
	NIBS (2007)	BIM is an entity with multiple features: it is a product, a process and a system to design, deliver and operate built assets.
	Building SMART (2014)	BIM is a process to create digital representation of physical and functional characteristics of a facility
BIM academics	Poerschke et al., (2010)	BIM is collaboration process by different stakeholders at different phases of the life cycle of a facility.
	Succar (2009)	BIM is a set of interacting policies, processes and technologies producing a methodology to manage the essential building design and operations of construction projects thought their life cycle.
	Azhar (2008)	A BIM model characterizes the geometry, spatial

	relationships, geographic information, quantities and properties of building elements, cost estimates, material inventories and project schedule
Hardin (2009)	BIM as a process of adopting and establishing a new notion of thinking.
Eastman at al., (2008)	BIM is not just a technology but a process, as vast as a multidisciplinary design, analysis, construction and facility management technology, as well as the harbinger of dramatic process change.
Abanda et al (2015)	BIM is a collaborative software that is used at different stages of construction.
Santos, Costa and Grillo (2017)	Modelling building information based on multiple aspects (e.g. spatial design, building structure, and energy)

Source: Researcher's Summary from Literature Review, 2023.

It can be concluded from the above definitions that BIM has been presented as a product (BIM model), an activity (process) to create a product, and a system to manage the activity and product, as represented in the Figure 2.1.

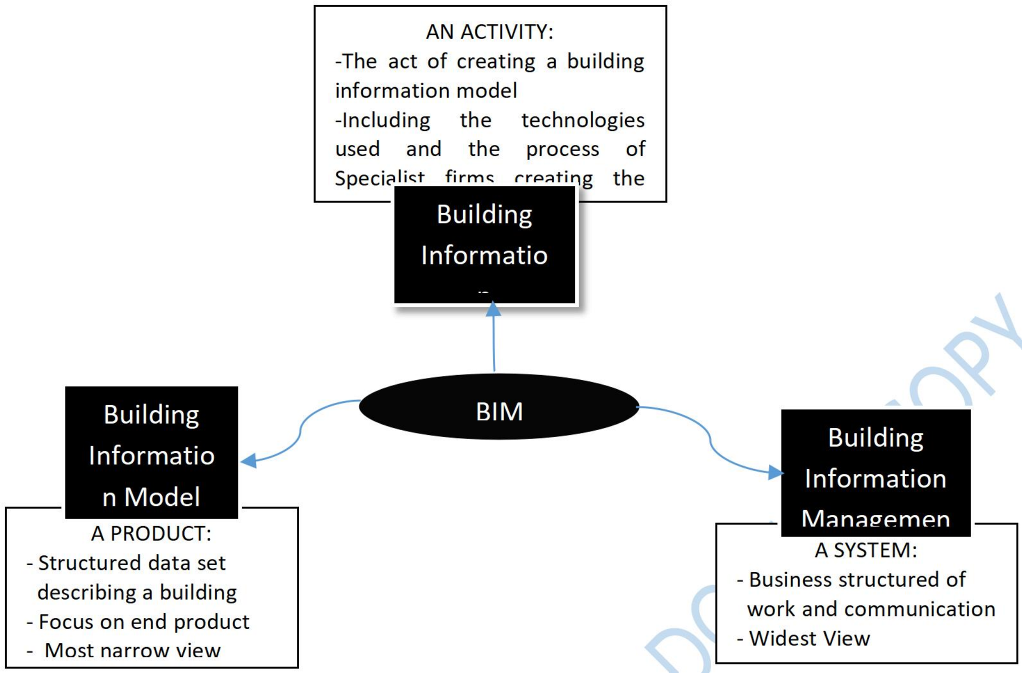


Figure 2.1: Summary of BIM Definition

Source:[86]

2.1.5.2 Dimensions in BIM

A basic building information model is an object-oriented 3D model with several implementations and uses throughout the project life cycle. The extension of BIM implementations over a project's life cycle is made possible by the model's ability to be a 4D, 5D, or nD model. The following sections provide a brief definition of these, which are known as BIM dimensions in the literature.

2.1.5.2.1 Three dimensional (3D) model

A basic design view is obtained by creating a three-dimensional (3D) model of a construction during the design stage, and is referred to as XYZ [87]. Clients, architects, and contractors can use 3D models for design collaboration and job clash identification [88]. These advantages enable the design to be developed at an early stage prior to construction, hence saving time (M. Othman et al. 2022).

2.1.5.2.2 Four dimensional (4D) scheduling model.

The "4D process" is the process of adding "time" to three-dimensional (3D) representations. By connecting the construction schedule to the 3D model, many participants can predict how activity will move during the construction stage or how long an operation will take in real time [89]. This enables full construction coordination, better cooperation, and the identification of potential bottlenecks [90]. It was further said that a contractor can decrease the project's timeframe by employing 4D models to predict where personnel, tools, materials, and space will be needed on a daily basis and for how long [91].

2.1.5.2.3 Five dimension (5D) cost model.

The five-dimensional (5D) model, which incorporates "cost," is stated as "time and cost." Its primary function is to determine the price of anything [92]. A construction project's overall cost can be calculated in 5D utilizing cost data for materials, labor, location, and size; cost data can be inserted into each item of the model, resulting in automatic cost estimation [93]. Furthermore, team members will meet online to discuss design changes, which may result in an immediate cost adjustment, but the entire project cost will be calculated by a cost estimator [94].

2.1.5.2.4 Six dimension (6D) sustainability models.

BIM has reached a new sixth dimension as a result of technological advancements (6D). The 6D addresses all aspects of building sustainability, including energy analysis [95]. The adoption of 6D technology would aid designers in correctly and completely estimating energy early in the design process, resulting in a reduction in overall energy usage [96].

2.1.5.2.5 Seven dimension (7D) facility management models.

BIM technology uses facility management, also known as 7D or the seventh dimension, and is described as a "as-built model" since the contractor modifies the model throughout the construction period [97].

2.1.5.3 BIM Maturity Level

The lack of complete clarity regarding the degree of BIM implementation and the scope of measurement led to the development of the BIM maturity stages. The maturity stages would identify various levels of BIM implementation by knowing the BIM fields. After the Pre-BIM phase or immediately following the Point of Adoption (PoA), which is a stage before the BIM implementation stage, the BIM stages are defined [98]. Three fixed starting points with an open ending point to account for potential future technological advancements are clearly described in the BIM maturity stages. It takes several incremental levels to move from one stage to another because the steps advance from one point to another through level advancement [99]. The stages are sort of supplementary elements to the BIM field types that specify the stage of BIM adoption or implementation; the stages include:

2.1.5.3.1 Level 0: Pre - BIM

Unmanaged CAD (Computer-aided Design) probably 2D and/or 3D, with paper (or electronic paper) exchange mechanism as the most likely data. That is, design disciplines who are designing, documenting and creating visualizations but who have not yet fully embraced object-oriented modeling and the concept of embedded information and/or appended/linked object information [100].

2.1.5.3.2 Level 1: Object-Based Modelling

When an object-based modeling tool (such as Revit, ArchiCAD, TEKLA, or BIM360) is used to create a single, multidisciplinary information-rich model during the design, construction, or operation stages, BIM is said to have been deployed. Utilizing 3D parametric tools, such as Revit, to build a 3D structure for the automation and visualization of 2D drawings and documentation is a requirement for BIM Level 1 [101]. The working procedure is very similar to the pre-BIM stage, and information sharing is still one-way only. Therefore, there is no cooperation among the stakeholders because the few changes are organizational in nature. The Design, Construction, and Operation phases of a single-disciplinary model do, however, have a lot in common.

2.1.5.3.3 BIM Level 2: Model-Based Collaboration

Following the completion of BIM Level 1, moving from single-disciplinary modeling to an inter-disciplinary model through the sharing of developed models is the next step (i.e. between Architect and Structural Engineer). BIM Level 2 is defined as the capacity to collaborate through the sharing of models (that support IFC) and the connection between two project lifecycles (i.e. Design-Design, Design Construction, and the Design-Operation)

(Kaewunruen, Sresakoolchai, and Zhou 2020). An exclusive 3D rich information model is used in this process because it will enable the exchange of different disciplines. Data extractions and subsequent advancements like 4D scheduling and 5D costing are now possible. As the traditional 2D workflow begins to vanish, new procedures and contract amendments emerge [102].

2.1.5.3.4 BIM Stage 3: Network-Based Integration

Integrated models that are semantically rich are created, shared, and maintained collaboratively throughout the course of a project at BIM Level 3, a revolutionary stage in the implementation of BIM [103]. The distinctive feature of this stage is the ability to track changes to the developed models and the existence of a single distributed federated database that houses all data from various professional stakeholders. The BIM Level 3 is a shared, interdisciplinary n D model that enables two-way access for the important project participants and the capacity for numerous analyses during the early stages of a project [104]. This stage of BIM implementation makes it easier to make adjustments to the way construction works are procured. including contract terms, risk sharing, roles, and responsibilities, as well as deliverables. All of these are related to technological advancement and policy change. In contrast to the conventional workflow, Figure 2.3 illustrates the collaborative BIM project initiation workflow.

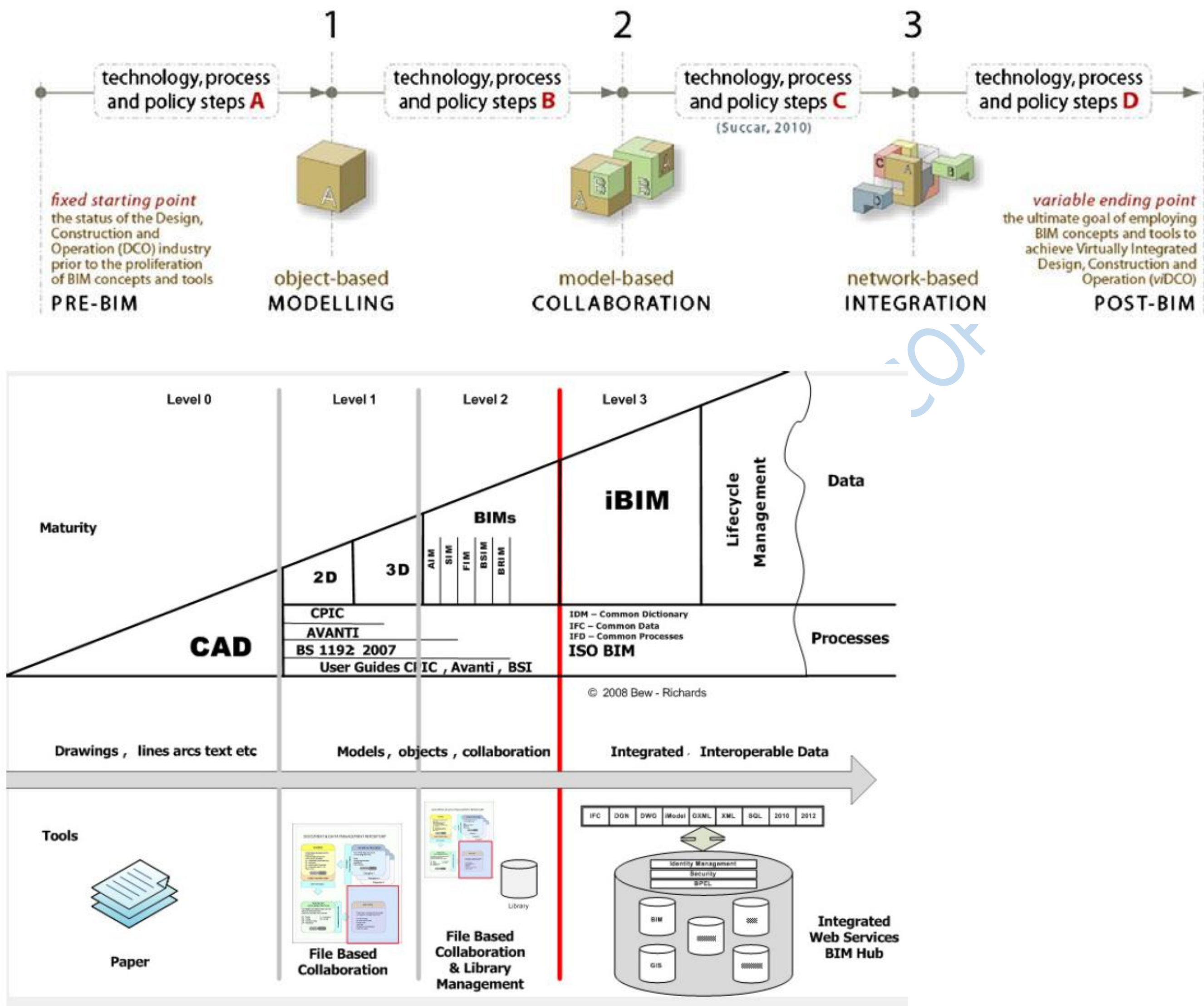


Figure 2.2: Bew-Richard's BIM maturity model

Source: [105]

2.1.6 The concept of BIM Adoption

Adoption of BIM results from raising awareness and persuasion; it involves seeing the concept as a novel approach to problem-solving. There are three levels of BIM adoption: Micro (within an organization), Meso (within a project), and Macro (market/national). The Micro BIM adoption relates to organizational (firm) adoption, with top management of a firm prescribing the BIM usage [106]. BIM adoption at the Meso level is based on projects and their teams, with the owner and project manager directing. Governments and international organizations are involved in the macro BIM adoption, which is related to markets and industries (countrywide) [107].

The potential of BIM to bring about significant changes in the construction industry has been widely acknowledged on a global scale. Initially seen as a new wave of technology to display and coordinate project data, BIM is today seen as a paradigm shift, a process-driven technique to enable collaborative working in the building projects that has many advantages from the idea stage to facility management and beyond. Numerous research initiatives, industry publications, and surveys have demonstrated that BIM has been successfully adopted in the majority of developed nations [108, 109]. Scandinavian nations, the US, UK, Singapore, Australia, Germany, etc. are good examples. According to a fairly recent survey by McGrew Hill, Japan, South Korea, and New Zealand will represent the next stage of BIM adoption maturity [110]. The adoption of BIM in countries that were early adopters is covered in the sections that follow.

2.1.6.1 BIM in USA

The USA has been a leader in BIM adoption over the past ten years and serves as a model for other nations looking to adopt and use BIM. The General Services Administration (GSA) mandated the usage of building information modeling throughout the design phase for new structures in 2006. The GSA, which started its BIM projects, 3D-4D, in 2003, is the primary public client utilizing BIM in the public sector in the USA. The National Institute for Standards and Technology (NIST) has carried out numerous research projects on various

BIM aspects and has produced reports, guidelines, and supporting documentation for BIM adoption that are used globally.

The US Army Corps of Engineers' CAD/BIM Technology Centre is a research facility that offers technical and professional services for BIM deployment across professional services in a way that ensures an acceptable return on investment and fosters interoperability between BIM and other geospatial technologies. The Corps of Engineers' Construction Engineering Research Laboratory is converting the use of BIM with the assistance of its other laboratories and is a key factor in the industry transition with products like COBIE (Construction Operations Building Information Exchange) [111]. Along with professional organizations like AIA and AGC, US academic institutions have actively contributed to the development of BIM standards and guidelines, which have aided BIM adoption and implementation not just in the US construction sector but also globally.

As a result, a number of early BIM initiatives in the USA that were successful and had a profitable return on investment (Plate 2.1 reflects an example project). The Sutter Heath Eden Medical Center is a 320-million-dollar facility located in Castro Valley, California.

Plate 2.1: An exemplary BIM enabled integrated project

Source: [112]

The figure 2.3 shows that USA is on top for BIM adoption and its adoption in USA is still growing faster than any other country.

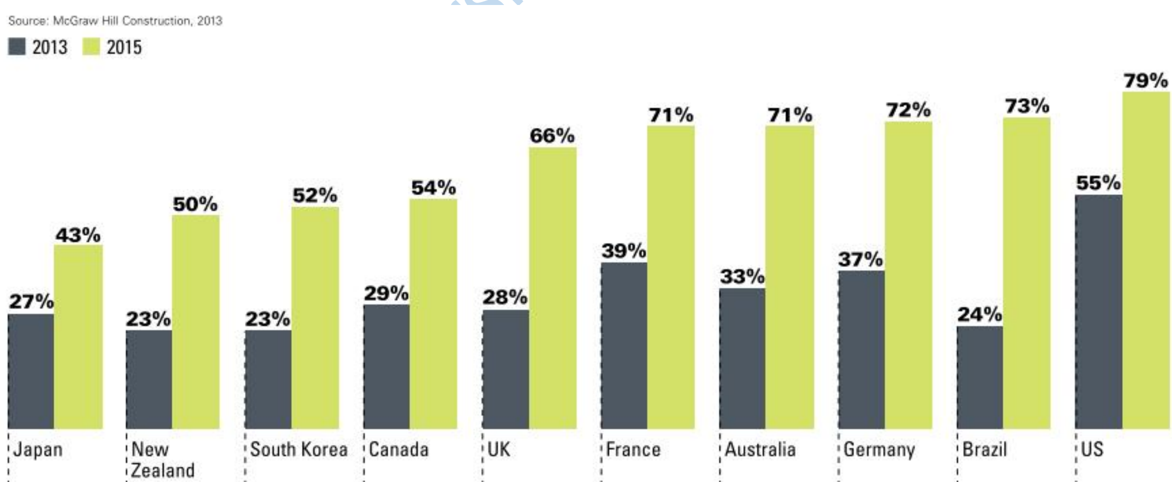


Figure 2.3: BIM Adoption Comparison of Different Countries

Source: [113]

2.1.6.2 BIM in Singapore

Singapore was at the forefront of digital technology adoption even before the term BIM became popular after 2003. The Building and Building Authority (BCA) developed the BIM Roadmap in 2010, with the goal of having 80 percent of the construction industry use BIM by 2015 [114].

In Singapore, the principal institution involved in the development and implementation of BIM for government projects is the Construction and Real Estate Network (CORENET). It is a major information technology effort initiated by Singapore's Ministry of National Development in 1995. Consulting engineers like as Arup and WSP have begun to use BIM in their projects in the private sector [115]. Plate 2.2 depicts several examples of BIM projects in Singapore.

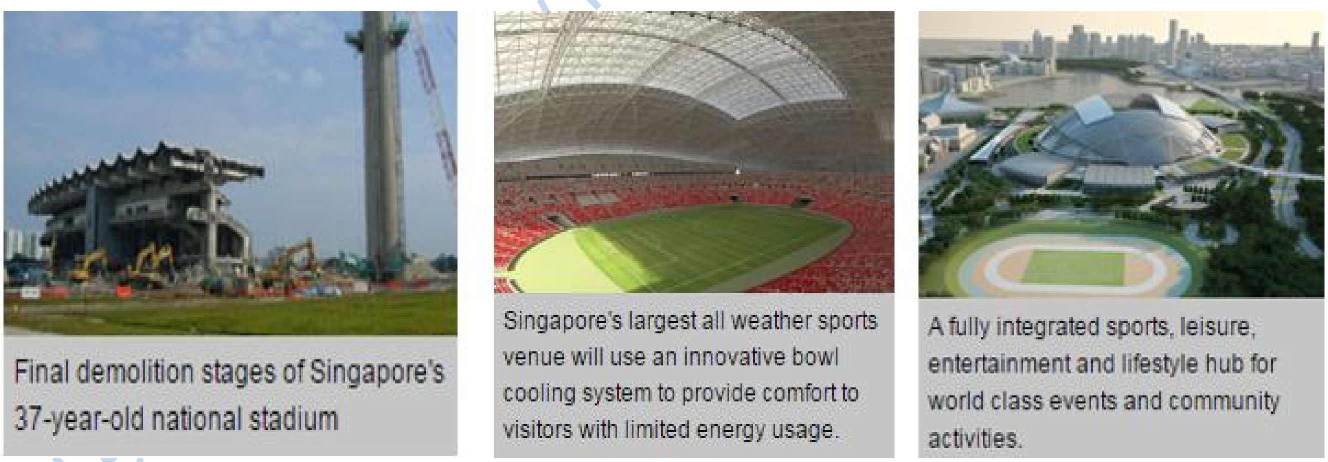


Plate 2.2: BIM project examples in Singapore

Source: [116]

2.1.6.3 BIM in Scandinavia

The Scandinavian nations (Denmark, Finland, and Norway) have made using BIM mandatory for important public-sector projects and are particularly advanced in this area. In Denmark, governmental clients including the Danish University Property Agency, the Palaces & Properties Agency, and the Defence Construction Service demand the usage of BIM for their projects [117]. At least three public owners—The Palaces and Properties Agency, The Danish University and Property Agency, and Defense Construction Service—have started working on BIM in Denmark.

Other public and private sector clients in Denmark, like Gentofe Municipality, KLP Ejendomme, Bips, etc., have recognized the benefits of BIM and required its implementation [118]. The state client advocating the usage of BIM in Norway is Statsbygg. The Norwegian Homebuilders Association promotes the adoption of BIM and IFC within the sector. Selvaag-Bluethink is creating IFC-based BIM in the private sector. The top company performing BIM research is SINTEF. Plate 2.3 displays a few sample BIM projects in Norway.

Furthermore, in Finland, Senate Properties, the government's agency for property services, has mandated the use of BIM since 2007 for its projects. BIM has been pushed in Finland by Tekla and the Association of Finnish Contractors in conjunction with state client senate properties. The academic institutions engaged in BIM R&D include Tampere University of Technology and Helsinki University of Technology. For BIM and other studies in the built environment, VTT is the main research agency in Finland [119]

Plate 2.3: Example BIM projects in Norway
Source: [120]

2.1.6.4 BIM in UK

After the UK Government's building strategy was announced in 2012 and required at least level 2 BIM on all important public sector projects by 2016, the use of BIM increased in the UK [121]. According to a 2012 survey by NBS (National Building Specifications), 39 percent of the industry now genuinely uses BIM, up from 13 percent in 2010. In the same time frame, the proportion of non-BIM users who were unaware of BIM fell from 43% to 6%.

However, whilst these numbers are encouraging, a rising proportion of the sector is aware of BIM but has yet to implement it. Concerns about the expected returns and investment costs still exist. Many in the business continue to be perplexed by the topic and lack faith in the promises made by BIM, despite the introduction of new UK BIM rules and assistance from the government. Positive feedback from individuals who have used BIM to deliver projects and can show a return on investment helps to balance this. The demand for training and development that can explain the reality of BIM, where it needs to go by 2016, and the creation of Level 3 remains quite great. Despite this caution, the UK is acknowledged as setting the global standard for enhancing efficient and effective construction information and putting BIM into practice.

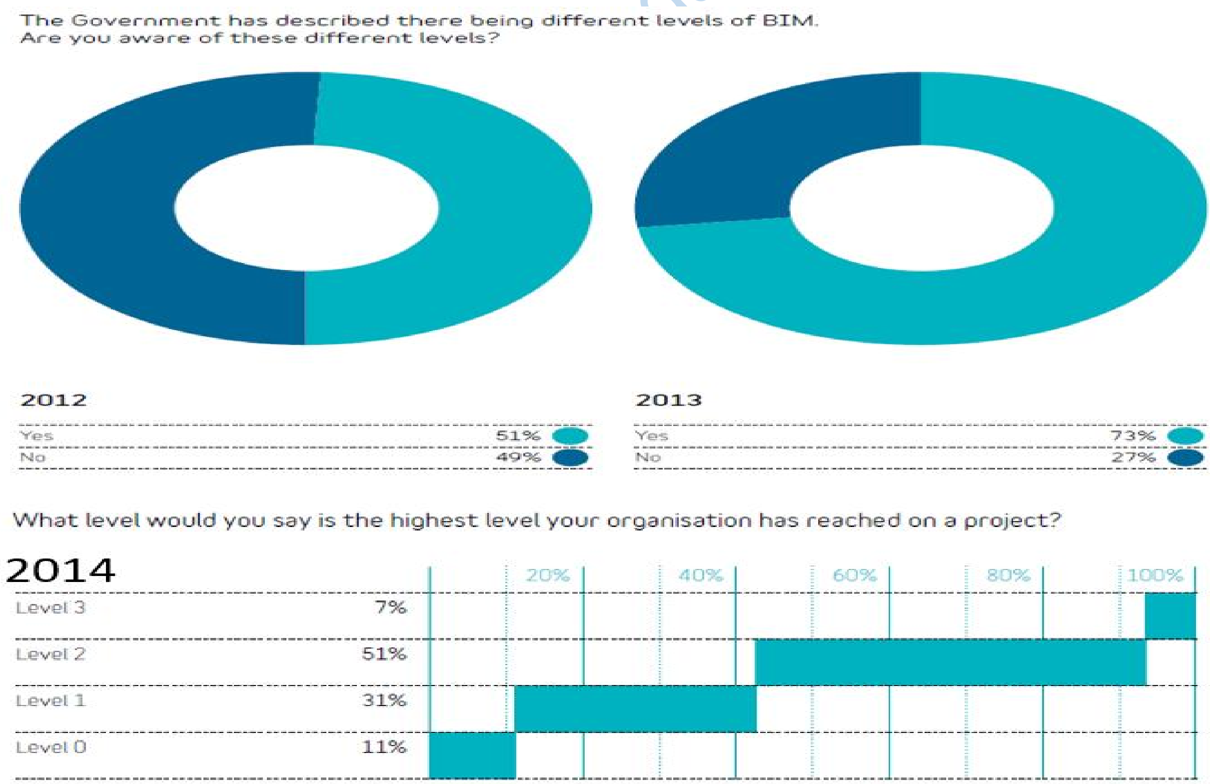


Figure 2.4: BIM Awareness and Adoption in the UK

Source: [122]

2.1.6.5 BIM in Australia and New Zealand

In the upcoming BIM maturity cycle, Australia and New Zealand are both attempting to join the list of countries. Although BIM was just recently introduced in that region, the market soon recognized its worth and got involved in actively creating the skills necessary for BIM adoption. More than 51 percent are currently using BIM on more than 30% of projects, and these numbers are anticipated to rise sharply in the years to come. More than 74 percent of the firms surveyed said they plan to use BIM on more than 30% of their projects in the upcoming two years [123].

2.1.6.6 BIM in Hong Kong

Another early BIM adopter is Hong Kong, where the Hong Kong Housing Authority (HKHA) has pioneered the adoption of BIM since 2006 for its public housing projects, enabling BIM-enabled design, sustainability studies, and construction coordination. The BIM initiative complies with the Works Branch of the Development Bureau of Hong Kong's BIM regulatory policy. At the HKHA's main office, a BIM center was established in 2009 to encourage the usage of BIM and facilitate experience sharing. Since 2006, HKHA has been testing the usage of BIM in brand-new public housing projects. According to its experience with BIM, cooperation, design optimization, construction planning, and conflict detection can all be improved with BIM. In the long run, the HKHA hopes that it will result in less waste and time savings [124]. In order to include BIM in all projects starting in 2014/15, HKHA will continue to apply it in additional projects.

However, HKHA intends to look into more application areas to make BIM a more user-friendly tool in Hong Kong, such as automatic bill of quantities extraction from BIM models, checking building codes to ensure compliance with building regulations, specification integration, prefabrication, and assembly RFID, etc. According to HKHA, BIM will soon go from being a "desired skill" to a "needed skill" in the AEC job market [125].

In conclusion, BIM is now a worldwide phenomenon, and more nations are pledging to embrace it. By 2016, all public-sector and projects costing more than S$50 million in South Korea had to use BIM, according to the Public Procurement Service. More recently, the EU parliament approved policies to encourage the use of BIM by its 28 member states [126]. Large clients and governments are promoting BIM adoption to cut down on capital expenditures and obtain high-quality construction projects as the advantages and value of BIM become clearer.

2.1.7 The Concept of BIM Uses

The use of BIM as a tool by various construction industry stakeholders varies from the beginning of construction to the end of the building's whole existence. The building stakeholders which may include but not limited to architects, engineers, quantity surveyors, builders and facility managers, whose responsibilities can overlap with those of other specialties [127]. At various points in a building's life cycle, BIM is used for the following:

2.1.7.1 Design Stage

Depending on the complexity of the project, the design team often consists of architects, structural engineers, services engineers, and builders [128, 129]. The design team must absolutely guarantee the building's constructability, beauty, structural soundness, and functioning [130]. The design team is then required to present the customer's requirements in an easily understandable way to the entire anticipated project team, particularly the client who will be funding the project [131]. The design stage of the building, which is the stage in which all decisions pertaining to what the building will be and consist of are made, plays a crucial role in the building's lifespan. The following are then the major uses of BIM in the design stage:

2.1.7.1.1 Construction planning

In a BIM-enabled project delivery, the sequencing and scheduling of project tasks are coordinated using BIM models in accordance with the available resources, time, and space. 4D modeling is the process of linking a traditional project plan (such as one created in Primavera or MS Project) with model elements to add time to a 3D model [132]. By utilizing several BIM tools, such as Autodesk Naviswork Manage or Synchro Professional, which can simulate building activities based on the Critical Path method (CPM) or line of balance as used in task planning, 4D models can be built [133]. In a simulated setting, 4D models can be utilized to convey construction sequencing, considerably improving the use of site resources, space usage, equipment and material acquisition, labor management, health and safety planning, and coordination with vendors and subcontractors [134].

2.1.7.1.2 Visualization

BIM is a very potent visualization technology that can provide photorealistic visualizations and animated simulations of the proposed design solution, both of which are very useful for helping other project stakeholders understand and communicate design intent [135]. Construction clients frequently express dissatisfaction with the finished project since the majority of them cannot comprehend the design in 2D and are consequently dissatisfied with the given product. Early in the project, visualization is a useful tool for communicating the knowledge of the design and final appearance of the finished product, which will lower the frequency of change requests from the customer and increase client satisfaction [136]. To get a competitive edge when bidding for new projects, contractors can leverage the visualization component of BIM to build 3D models, animated walkthroughs, and sequencing of project components [137].

Additionally, project teams can work together internally and optimize the building process with the aid of visualization and simulation of project components. Contractors have the ability to model construction activities in a 4D environment and anticipate the construction sequencing and resource requirements. As health and safety analyses can be carried out more effectively with BIM's visualization features, simulations in 4D also aid in reducing the number of incidents that occur on the job site [138].

2.1.7.1.3 3D coordination

Building systems can be coordinated using the 3D BIM model before being manufactured and deployed on site. Before installation, all electrical, plumbing, mechanical, structural, and architectural systems are checked, and any conflicts are found and resolved using conflict, interference, collision, or clash detection technologies [139]. The adoption of BIM has resulted in certain projects reporting a reduction in site-related inquiries and conflicts of up to 80% [140].

2.1.7.1.4 Cost estimation

Cost estimation is the process of calculating the predictable resource costs to finish specific tasks of a building project. While other industries set the selling price after production, the building industry must decide the selling price of building materials even before construction begins. Construction projects are therefore quite risky, and their success only rests on how accurately the costs are estimated [141]. This process allows the project team to see the cost effects of their changes, during all phases of the project, which can help curb excessive budget overruns due to project modifications [142].

Specifically, BIM can provide cost effects of additions and modifications, with the potential to save time and money and is most beneficial in the early design stages of a project. The use of BIM for developing cost estimates would minimise the efforts and time and increase the accuracy [143]. In addition, BIM has come in place to solve traditional cost calculation which requires manual take-offs from numerous 2D building documents, which is a time-consuming operation. When the inputs change, manually updating the cost estimates is complex and time consuming because human calculations must be conducted again for the changes [144].

2.1.7.1.5 Prefabrication

Prefabrication is an idea that construction researchers have consistently backed by moving as much of the construction workload to factories where controlled conditions can be used for increased productivity [145]. In order to achieve the required cost and quality in controlled environments, prefabrication of construction experts can apply a variety of productivity improvement techniques. Because they give workers consistency and enable quicker and more efficient planning of materials, standard size materials increase productivity rates (Borrmann et al. 2018). Prefabricated parts can be easily put together on site, saving a great deal of time and effort that would otherwise be needed for shop drawings, submittals, design modifications, and approvals [146].

However, prefabrication, still needs precise and accurate data to begin the manufacturing process, which is challenging with traditional 2D CAD because exact dimensions aren't known until very late in a project [147]. For instance, measurements of the site's current conditions must be taken before MEP (mechanical, electrical, and plumbing) system details can be created. These measurements are then compared to shop drawings and filed dimensions for confirmation. Prefabrication has been shown to significantly increase construction productivity [148], but it necessitates precise information during the design phase, which is challenging with conventional CAD systems. Building information models can provide this information with greater accuracy and integration.

In the prefabrication industry, BIM is one of the most useful technologies because most construction components are constructed in a controlled environment. The creation of shop drawings for various building systems is simple [149]. Because of the quicker construction assembly, lower labor costs (both skilled and unskilled), less site congestion, and lower inventory levels, health and safety are improved [150].

2.1.7.1.6 Constructability analysis

"Designers occasionally get carried away with their work and may create something that is practically and structurally impossible to build," stated one anonymous designer critic [151]. When this occurs, BIM gives the contractor the option to give the designers a constructability review. To make sure the design can be produced in the field to match a specified schedule and cost, this would entail a variety of buildability tests and an examination of alternative approaches [152].

2.1.7.1.7 4D Scheduling and Sequencing

The realistic sequencing and budgeting of building activities saves substantial money and time by reducing rework and schedule delays [153]. The "4D" model is created by combining the 3D model with the CPM schedule, with time as the fourth dimension [154]. With this, 'phase optimization' may be accomplished and clearly communicated to the entire project team as to what and when will occur on the construction site [155].

2.1.7.2 Construction / Building Stage

At this point, decisions have been made regarding building, funding, and facility administration, and actual construction of the facility is currently under way. The client's design team has chosen the contractors, and they will oversee and supervise the construction phase. The contractor(s) will be given the design details and the 3D model of the building, and they will be asked to provide a clear and concise addition regarding their expertise on the constructability and a range of issues that are likely to arise during the building's use [156]. Some authors have emphasized construction monitoring and modeling, as well as manufacturing, as the key applications of BIM tools throughout the building stage [157, 158]. The contractor's team, which includes an architect, quantity surveyors, engineers, masons, and other professionals as needed, can visualize a stage-by-stage simulation of the construction process using the BIM model. This makes it easier for everyone to do their jobs because it allows the professionals to resolve constructability, durability, cost effectiveness, and suitability issues during the construction process [159, 160,161].

2.1.7.2.1 Construction Monitoring

The arrangement of temporary structures and transportable machinery, as well as traffic access routes during execution times, can all be predicted using 4D models (e.g. Trucks, cranes, excavators etc). With the use of 4D models for site logistics planning, it is possible to apply a "just in time" method for managing materials and labor, which reduces waste, lowers costs, and makes better use of project resources [162].

2.1.7.2.2 Clash detection

The Clash Detective tool makes it simple to spot interference clashes between different 3D solid objects in a 3D model and to investigate and report them. Users can use the clash detection to selectively look for conflicts between any two systems, including mechanical, plumbing, electrical, and structural systems [163]. All the subcontractors and suppliers submit their respective models (which are typically produced using different design packages) and then, the BIM manager provides one platform on which all the models are combined into one file to be viewed as one composite model [164]. The majority of design flaws or conflicts are discovered at this point.

2.1.7.2.3 Maintenance Scheduling

2.1.7.2.4 Fabrication

2.1.7.3 Operation / Facility Management Stage

Researchers have found that this stage of construction suffers from a high level of neglect, which has caused serious infrastructural degradation in the country [165, 166, 167, 168, 169, 170, 171, 172, 173]. By incorporating operational and management decisions into the design of the facilities, where the function of each space has been determined, the maintenance has been planned and scheduled, and the functionality of the components inherent in the facilities can carry the anticipated population without deficiencies, this problem can be made easier [174].

Additionally, as stated by [1]a study, the future of effective and efficient facility management depends on how quickly the industry has embraced the BIM for the management of buildings, particularly high-rise buildings, which are known to present facility managers with significant challenges due to the numerous aspects and components inherent in such structures [175]. As a result, this facility management duty is further separated into a number of subtasks, each of which can benefit from BIM's increased efficiency [176].

Building System Analysis, another subtask of facility management duty is used to assess the condition of a building. BIM can also be used to manage assets, with spaces that are adequately allotted to each use and visual simulation tools that are available on the BIM platform [177]. More significantly, the record model is completed by taking into account changes made to the building use and spaces during the post-construction phase [178].

Due to the scarcity and inadequacy of such highly qualified and licensed Facility managers, the task of operation and management is exclusively the responsibility of Facility managers. However, this role is occasionally performed by other professionals like Quantity Surveyors and Estate Surveyors [179]. This is a new method of managing buildings that BIM is promoting, and BIM will enable them to carry out well-planned maintenance that is consistently adhered to [180].

- Asset Management
- Building System Analysis
- Record Modelling

When a project reaches the handover phase, construction management or the contractor can give the owner a copy of the BIM model that contains all the required information as built information. This record model includes links to submissions, warranty details, insurance details, and maintenance guides, as well as information from manufacturers and subcontractors about the operation of installed equipment. This record model also serves as a database for security-related data, including locations of fire safety equipment like fire alarms and sprinkler systems, as well as emergency exits and walkways [181]. The facility manager can plan for the energy consumption of building operations using the built-in information in the model [182].

Additionally, the record model allows for the tracking of the placement of furniture, equipment, and MEP installations, which can improve the planning and execution of any restoration or refurbishment jobs later on in the project life cycle. The record model's data can be used to forecast operational expenses and manage the cost impact of construction and maintenance projects. BIM expert contractors may benefit from the increased preference for

BIM implementation on projects among project owners due to the usage of BIM for facility management [183].

Table 2.2: Summary of selected BIM Uses as found in literature

STAGES	BIM (Uses)
Design Stage	Cost Estimation
	Construction Planning
	3D Coordination
	Prefabrication
	Visualization
	Constructability Analysis
	Sequencing
Construction Stage	Construction Monitoring
	Clash Detection
	Maintenance Scheduling
	Fabrication
Maintenance/ Operation Stage	Asset Management
	Building System Analysis
	Record Modelling

Source: Source: Researcher's Summary from Literature Review, 2023.

2.2 Theoretical Review

From the review of the literature, several studies have revealed that many theories have explained the concept of innovation diffusion and adoption process. Some theories were concerned with adoption at a personal level, while others dealt with adoption at the organizational level. The major theories that explain the adoption of innovation at the personal level are the Theory of Reasoned Action (TRA), and the Technology Acceptance Model (TAM) [184]. Rogers's Diffusion of Innovation (DOI) Theory and the Technology, Organization, and Environment framework (TOE) are theories that explain the adoption of innovation at the organizational level [185]. Thus they are all considered very relevant to this research.

In the development of a conceptual framework for this research work, some theories and models were reviewed to give an understanding of the relationship that exists among the factors that affect diffusion and adoption of innovation. Innovation was defined as any idea, behavior, practice, or object perceived as new by its users [186]. A atusy described organization innovation as "the generation and application of new ideas, practices, or non-trivial change and improvement to an organization's process/methods, products/ technology or system of operation aimed at improving performance" [187]. It was further explained that an innovation does not have to be necessarily new, it might have been invented a long time ago but it is perceived new by its present audience. How new an idea or a practice is perceived by an audience depends on the level of awareness and knowledge of the audience about such an innovation [188]. Therefore, in then Nigerian context, a study made it clear that building information modelling BIM is a relatively new idea in the AEC industry even though it has been adopted in other countries as revealed in literature. Following Rogers' definitions of an innovation, building information modelling can be called an innovation in the Architecture, Engineering and Construction AEC industry [189].

The aim of this research is to establish a clear understanding of the diffusion and adoption of BIM as an innovation or tool with a view to identifying the impact of its adoption on communication and collaboration for timely and cost efficient delivery of projects by AEC industry in Nigeria. It further presents a graphical illustrations of the concepts of adoption and the relationship that exists among the factors that effects adoption of innovation in the AEC industry. Therefore, this section seeks to study and employ some of the most used theories and models in innovation diffusion and adoption in AEC industry. Consequently, this section discusses some of the models mentioned earlier.

2.2.1 Rogers Diffusion of Innovation Theory

Everett Rogers developed the Diffusion of Innovation Model in 1962, and since then the theory has been widely revised and adopted for studies in diffusion and adoption of technology and innovation. The Diffusion of Innovation (DOI) Theory helps to explain innovation diffusion and adoption both at individual and organizational levels. It further highlights how information about an innovation reaches its users [190, 191].

Rogers clearly defined adoption as the best decision taken by a person, organization or the unit of adoption at a time to fully use an idea. Diffusion was also defined as the process through which communication of innovation is carried out through some channels in a society. Innovation itself is an idea (process, service or product) perceived by a decision making unit as new. The fact that the idea is perceived to be new implies there might be some level of uncertainty in the decision making unit (a person, an organization or community). Therefore, Rogers' definitions revealed that although diffusion and adoption are stages in the Diffusion of Innovation Theory, both cannot be separated from each other, as diffusion is part of the processes that lead to adoption [192].

Rogers identified five major elements as important in diffusion and adoption of any innovation. These are the innovation, communication channels, communication time, society or social system, and other factors such as the characteristics of the decision making unity.

2.2.1.1 Main Elements in the Diffusion of Innovations

2.2.1.1.1 Innovation

An idea, activity, or initiative that is seen as novel by a person or other unit of adoption is referred to as an innovation [193]. Although an innovation may have existed for a very long period, for certain people it may still be novel. The novelty feature of adoption is more closely tied to the three steps of the innovation-choice process (knowledge, persuasion, and decision), which will be covered later. Rogers also asserted that there is a dearth of diffusion studies on technological clusters. It was further stressed, that "a technology cluster consists of one or more distinct technological components that are thought to be tightly related".

The acceptance of innovations is hampered by uncertainty. The changes that come from the adoption or rejection of an innovation in an individual or societal system are known as repercussions, and they can raise uncertainty [194]. People should be made aware of all the implications of the innovation's advantages and disadvantages in order to lessen their doubt about embracing it. In addition, according to Rogers, repercussions can be categorized as expected versus unexpected, desired against unpleasant (functional or dysfunctional), immediate versus indirect (outcome of the immediate result), and expected versus direct versus indirect (recognized and intended or not).

2.2.1.1.2 Communication Channels

Communication channels are the second component in the spread of innovations process. Communication is "a process in which people create and share knowledge with one another in order to attain a shared understanding" [195]. These channels allow for this communication between the sources. According to Rogers, "a source is a person or a group that creates a message. A message travels through a channel from its source to its recipient. An innovation, two people or other units of adoption, and a communication route are all communication aspects that Rogers claims are part of the special type of communication known as diffusion. There are two communication channels: interpersonal communication and the mass media. Interpersonal channels consist of two-way communication between two or more individuals, as opposed to mass media channels, which comprise a mass medium like TV, radio, or newspapers.

However, "diffusion is a very social process including interpersonal communication ties" [196]. As a result, interpersonal channels have greater potential to influence an individual's strong attitudes. However, the diffusion of innovations requires at least some degree of heterophony, which is "the degree to which two or more individuals who interact are different in certain attributes." Homophile is defined as "the degree to which two or more individuals who interact are similar in certain attributes, such as beliefs, education, socioeconomic status, and the like" in interpersonal channels. In reality, "participants are typically extremely heterophilous, which is one of the most characteristic issues in the transmission of innovations" [197].

Moreover, Localite and cosmopolite channels of communication, which connect members of a social system with external sources, can also be classified as forms of communication. When compared to interpersonal channels nearly all mass media outlets are cosmopolite, whether they are local or global. Due to the features of these communication channels, the knowledge stage of the innovation-decision process places a greater emphasis on mass media and cosmopolitan networks, whereas the persuasion stage of the process places a greater emphasis on local and interpersonal channels [198].

2.2.1.1.3 Time

The time component is frequently overlooked in behavioral studies. He contends that diffusion research exhibits one of its strengths by including the time component. A time dimension is present in the innovation-diffusion process, adopter classification, and adoption rate [199].

2.2.1.1.4 Social System

The final component of the diffusion process is the social system. A social system is "a collection of interconnected units engaging in cooperative problem solving to achieve a common purpose" [200]. Since innovation dissemination occurs inside the social system, the social structure of the social system has an impact. Structure, in the words of Rogers, is "the patterned groupings of the components in a system". He added that the primary criterion for classifying adopters, an individual's capacity for innovation, is influenced by the nature of the social system.

2.2.1.2 The Innovation-Decision Process

The innovation-decision process is "an information-seeking and information-processing activity, where an individual is motivated to reduce uncertainty regarding the benefits and drawbacks of an innovation". The innovation-decision process consists of five steps: (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation. Normally, these phases occur in the order of the passing of time [201]. Figure 2.5 illustrates this approach.

2.2.1.2.1 The Knowledge Stage

The knowledge stage is where the innovation-decision process begins. In this step, a person discovers the existence of the innovation and looks for information about it. The crucial inquiries throughout the knowledge phase are "what?" "how?" and "why? ". This stage involves trying to understand "what the innovation is, how and why it works". Rogers claims that the inquiries produce knowledge of three different kinds: three types of knowledge: awareness-knowledge, how-knowledge, and principles-knowledge [202].

Knowledge about an innovation's existence is represented by awareness-knowledge. A person may be inspired to study more about the innovation and then embrace it as a result of this information. How-to knowledge, which is the second type of knowledge, consists of instructions on how to use an innovation properly. Even professors with technical skills may not employ technology in the classroom if they do not know how to use it properly [203].

Because students require assistance in order to use technology successfully for education, it is not used to the expected extent [204]. According to Rogers, this information is a crucial factor in the decision-making process for innovations. Prior to the trial of an innovation, a person should be sufficiently knowledgeable about how to use it in order to increase the likelihood that it will be adopted. For reasonably sophisticated technologies, this understanding is therefore much more crucial.

The final category of knowledge is principles-knowledge. The operating theories that explain how and why an innovation functions are part of this knowledge. While an innovation can be embraced without this information, its discontinuation could result from misuse of the innovation. The main obstacle to faculty using technology in the classroom, is that faculty lack a clear understanding of why or how to do so [205]. Technology education and practice should offer both know-how and know-why experiences in order to generate new knowledge [206]. In actuality, even if a person possesses all the essential knowledge, this does not guarantee that they will adopt the innovation because a person's attitudes play a part in whether or not the innovation is accepted or rejected [207].

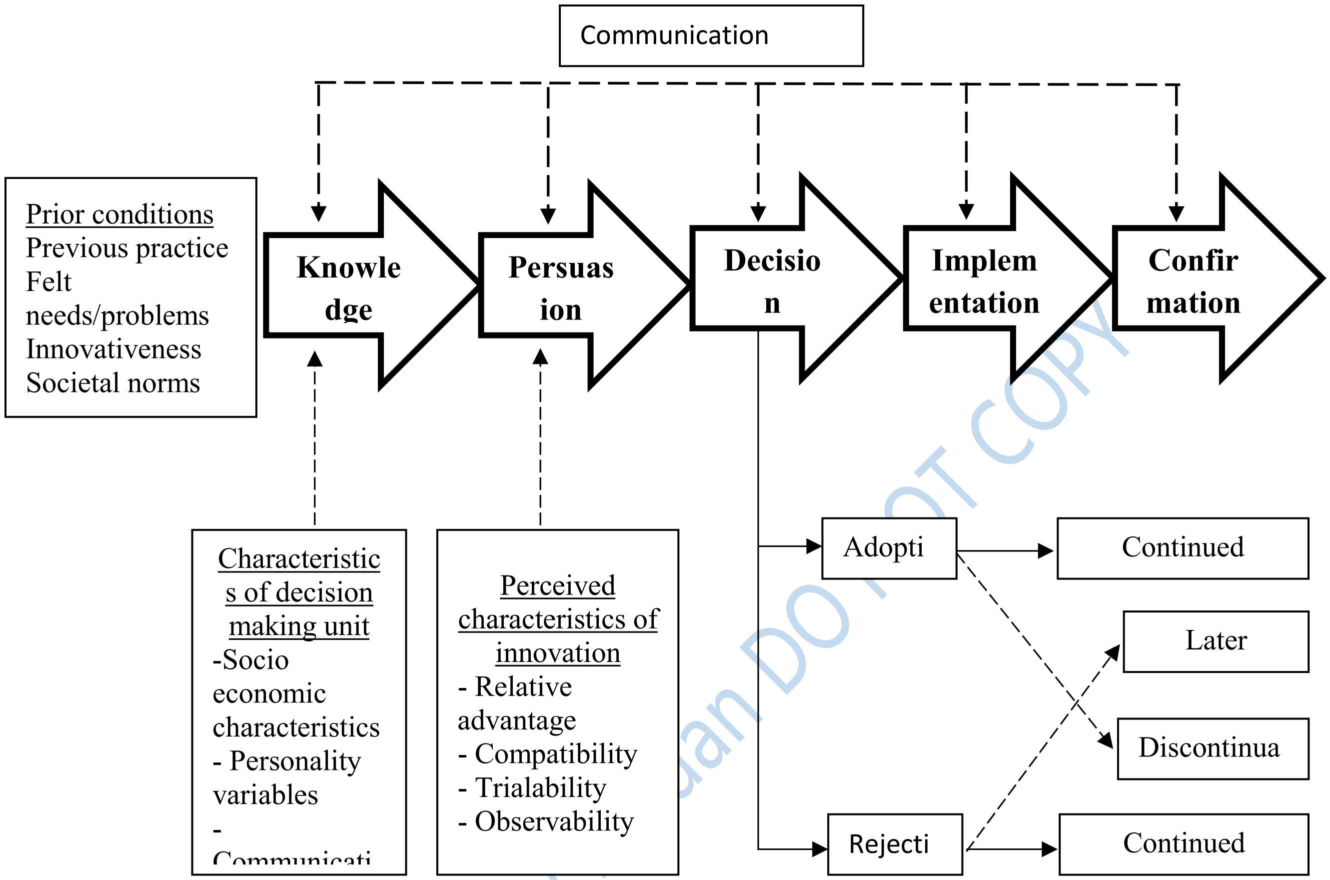


Figure 2.5: Rogers Diffusion of Innovation-Decision Process Model.
Source: [208]

2.2.1.2.2 The Persuasion Stage

Although "the establishment of a favorable or unfavorable attitude toward an innovation does not necessarily lead directly or indirectly to an acceptance or rejection of an innovation," the persuasive phase takes place when the person has a positive or negative attitude toward the innovation [209]. The persuasion step in the innovation-decision process comes after the knowledge stage since the individual forms his or her attitude after learning about the invention. In addition, Rogers claims that the persuasion stage is more emotive (or feeling) focused, whereas the knowledge stage is more cognitive (or knowing) focused. As a result, at the persuasion stage, the individual is more sensitively involved with the innovation.

Individual attitudes and beliefs regarding the innovation are influenced by the degree of uncertainty surrounding its functionality and social reinforcement from others (colleagues, peers, etc.). While information about a new innovation is frequently available from outside experts and scientific evaluations, teachers typically seek it from trusted friends and colleagues whose subjective opinions of a new innovation are most convincing. Through the decision step, people keep looking for information and messages about innovation appraisal [210].

2.2.1.2.3 The Decision Stage

The individual decides whether to accept or reject the innovation during the decision stage of the innovation-decision process. Rejection indicates "not to adopt an invention," whereas adoption refers to "full use of an innovation as the best course of action available" [211]. Since most people prefer to experience an innovation in their personal situation before making an adoption choice, innovations that have a partial trial basis are typically adopted more swiftly. The innovation-decision process can be accelerated by the vicarious trial.

However, at any point in the innovation-decision process, rejection is conceivable. Active rejection and passive rejection are two different sorts of rejection that Rogers described. In a situation of active rejection, a person tries a new innovation and considers adopting it, but ultimately decides against doing so. A decision to discontinue using an innovation after initially embracing it might be viewed as an active kind of rejection. The person does not even consider adopting the innovation when they are in a passive rejection (or non-adoption) stance. According to Rogers, previous diffusion research has not sufficiently discriminated between and researched these two types of rejection. In rare circumstances, the knowledge-persuasion-decision phases might be completed in the reverse order. This order exists, and group impact on innovation adoption can change a person's personal innovation decision into a collective innovation decision, especially in collectivistic societies like those in Eastern nations [212]. The implementation stage, however, always comes after the decision stage.

2.2.1.2.4 The Implementation Stage

An innovation is applied during the implementation stage. However, an invention introduces the newness in which "some degree of uncertainty is involved in diffusion" [213]. At this point, uncertainty regarding the innovation's results can still be an issue. Thus, in order to lessen the level of ambiguity regarding the outcomes, the implementer may require technical support from change agents and others. Additionally, the decision-making process for innovations will come to an end since "the invention loses its distinctive quality as the individual identity of the new concept fades" [214].

Reinvention is a crucial component of this stage because it typically occurs during the implementation phase. The term "reinvention" refers to "the extent to which a user changes or modifies an innovation during the adoption and implementation phase" [215]. Additionally, Rogers clarified the distinction between innovation and invention. While "a new concept is discovered or generated via the process of invention," "a new idea is used through the process of innovation adoption" [216]. Rogers went on to say that innovation gets adopted and institutionalized more quickly the more times it is reinvented. Computer technologies are more open to reinvention since they are innovations with a wide range of potential uses and opportunities.

2.2.1.2.5 The Confirmation Stage

The decision to innovate has already been taken, but at the confirmation stage, the person seeks evidence to support the choice. It was asserted that this choice may be overturned if the person is "exposed to competing information regarding the innovation" [217]. However, the person prefers to avoid unpleasant messages and look for affirming messages that support their choice. As a result, at the confirmation stage, attitudes become more significant. This stage is when subsequent adoption or discontinuance occurs, depending on the degree of support for the innovation's adoption and the person's mindset.

Discontinuance can happen in one of two ways during this phase. In the beginning, the person rejects the invention and replaces it with a superior innovation. Replacement discontinuance is the name given to this kind of discontinuation decision. Disenchantment discontinuance decisions are the alternative sort of discontinuation choice. In the latter, the individual rejects the invention because he or she is dissatisfied with how well it performs. The innovation not meeting the individual's needs could be another justification for this kind of discontinuance choice. Therefore, it does not offer a perceived relative advantage, which is an innovation's primary characteristic and influences the rate of adoption

2.2.1.3. Attributes of Innovations and Rate of Adoption

In order to reduce uncertainty regarding innovations, a study referred to the innovation-diffusion process as "an uncertainty reduction process" [218]. He then suggests characteristics of innovations that can do this. The term "attributes of innovations" refers to five aspects of innovations: relative advantage, compatibility, complexity, trialability, and observability. All these have earlier been explained.

.2.2.2 Task Technology Fit Model

The Tasks Technology Fit (TTF) model is another technology acceptance theory from information system literature that can match technology implementation requirements to the demands of the tasks assigned. As demonstrated in Figure 2.6, TTF models have three constructs: "task characteristics," "technology characteristics," and "person characteristics." The last outcome variable, "performance," is influenced by the "technology fit" principle, which is influenced by all three components. The TTF model's constructs describe how technology can assist a job task by "fitting" the requirements of that task to the capabilities of the technology that has been adopted [219].

According to the TTF model, technology can only be used at work if the tools given to the employee are appropriate for completing the task that was assigned to them [220]. Users with experience will select the tools and features that will best help them to complete their tasks with positive outcomes [221].

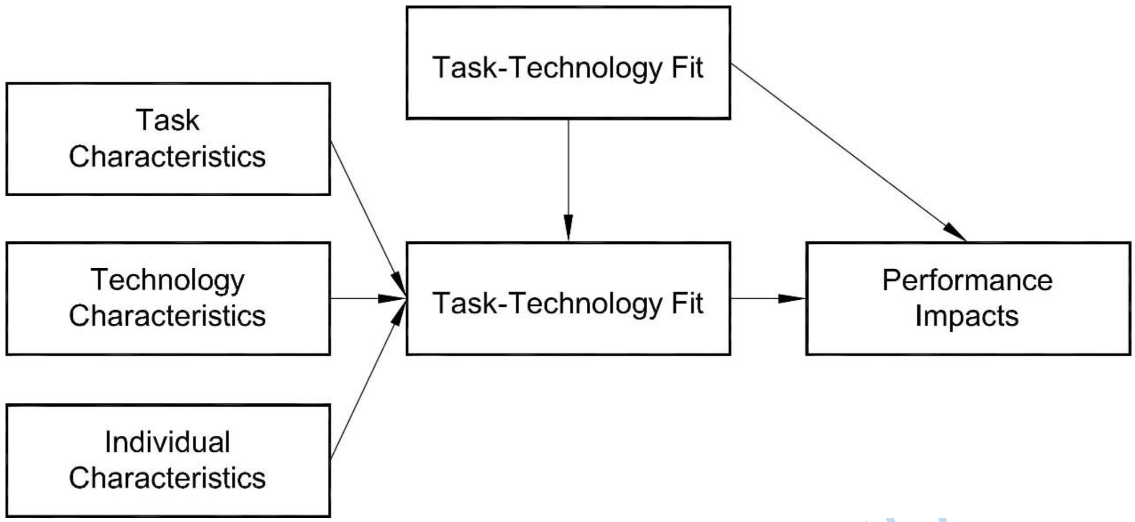


Figure 2.6: Tasks Technology Fit Model

Source: [222]

2.2.3 Technology Acceptance Model (TAM)

The theory of planned behavior and the theory of reasoned action served as the foundation for the development and extension of the Technology Acceptance Model (TAM) and its updated iteration TAM2 [223]. The basic goal of TAM is to identify the factors that influence a person's decision to embrace a cutting-edge technology in any business. The model makes an effort to describe user behavior across a number of different computing systems.

Figure 2.7 explains the connections between the model pieces in TAM. The model depends on two assumptions to determine the behavioral intentions for utilizing a specific technology: "perceived ease of use" and "perceived usefulness." The idea that using technology will enhance one's ability to accomplish one's work is known as "perceived usefulness." The notion that using a piece of technology will be simple to use is referred to as "perceived ease of use." According to TAM, external factors like training, the development process, and organizational roles could have an impact on a person's behavior about their intention to use technology [224].

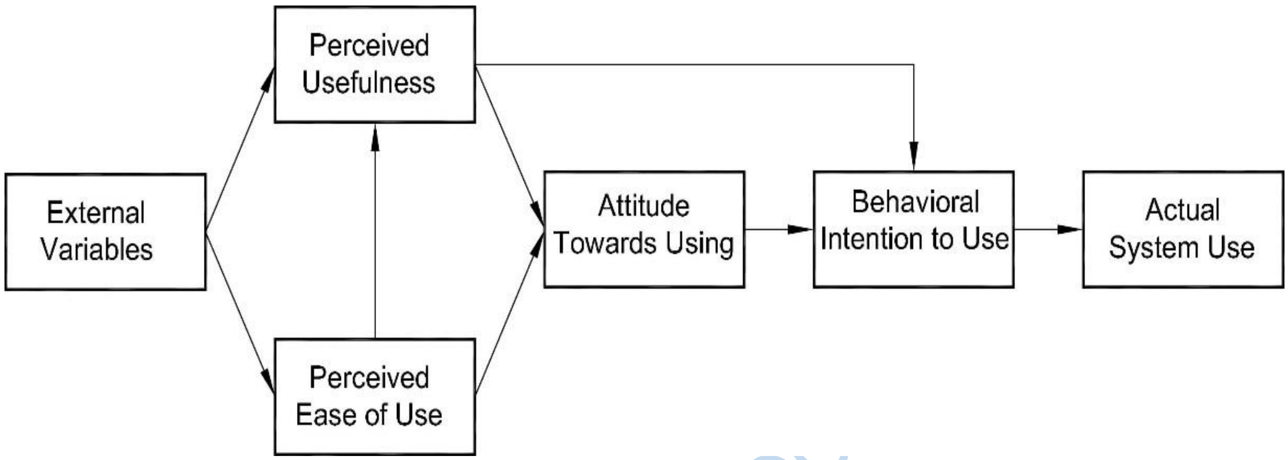


Figure 2.7: Technology Acceptance Model

Source: [225]

Two significant improvements to the technology acceptance model to create the technology acceptance model 2. were made (see Figure 2.8). First, subjective norms which only had an impact on the intention to use if the user was required to use the technology and not willingly. Second, external variables were defined and their connections to the model constructs were revised [226]. As a result, TAM2 expanded TAM categories by including "subjective norms" as an additional predictor for "intention to behavior" in situations involving forced use. Also expanded the TAM's "external factors" into TAM2's "output quality," "voluntariness," "results demonstrability," "experience," "job relevance," and "image."

TAM2 was later revised to become TAM3, as shown in Figure 2.8. TAM3 included additional mediators that have a direct impact on "perceived ease of use," ultimately impacting the user's "intention to behavior," whereas TAM2 extended the external variables to mediators or influences that have an effect on "perceived usefulness." Perceived delight, computer anxiety, perceived external control, computer self-efficacy, objective usability, and computer playfulness are some of these mediators [227].

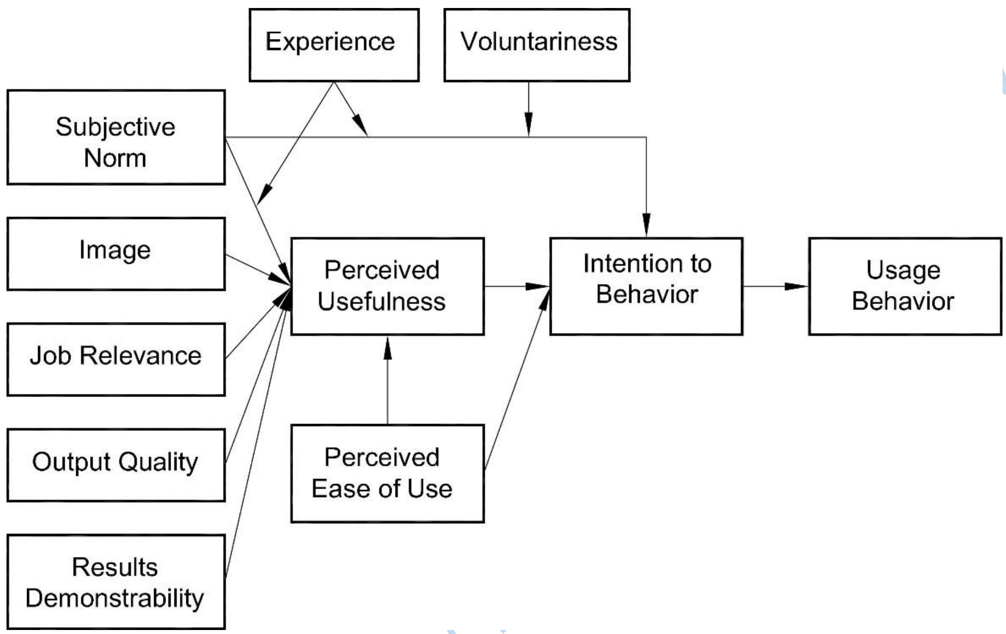


Figure 2.8: Technology Acceptance Model 2

Source: [228]

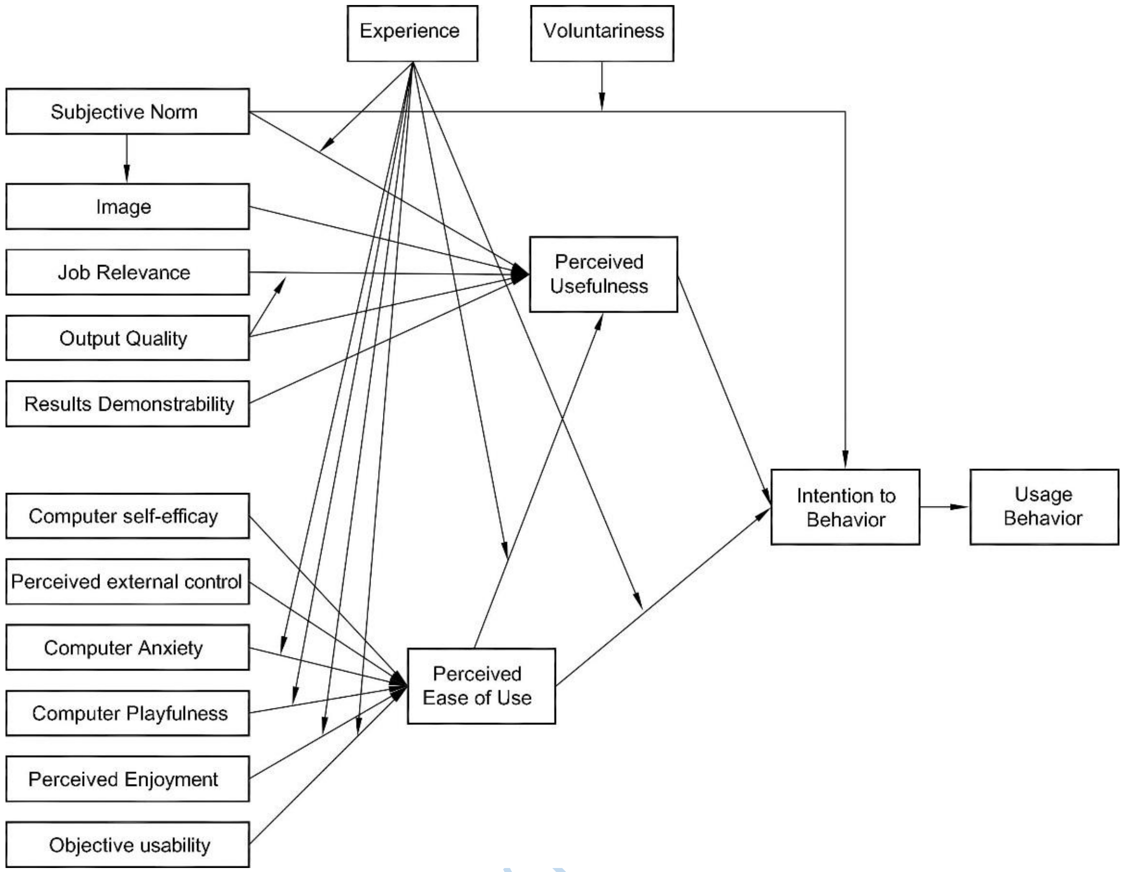


Figure 2.9: Technology Acceptance Model 3

Source: [229]

A number of scholars have examined the technology acceptance model and believe that several of its characteristics, particularly perceived utility, are insufficient or have only a small amount of application outside of the workplace [230]. This appears to be the result of the structures of TAM failing to capture the variety of jobs performed by end users or the limits imposed by vastly different working environments. Management control, customer satisfaction, task innovation, and task productivity were found to be invalid for net benefits [231]. A study criticized the TAM and TAM2 versions for lacking factors that adequately capture the change in organizational culture and the business process [232].

Metrics like "increasing job performance," "enhancing job effectiveness," and "accomplishing tasks more rapidly" are not reliable indicators of perceived usefulness. It was discovered that the use of ICT, whether it was optional or required at work, would result in inconsistent findings from information system research [233]. The results of empirical information system research on the effectiveness of ICT adoption have frequently been contradictory [234]. Since it appears that users' views of ICT influence do change over time and among social groupings, perceived usefulness should not be viewed as having a static quality [235]. A study contended that the importance of re-invention and learning in gauging perceived usefulness has been underappreciated. It was further asserted that TAM has been ignored and has diverted researchers' focus away from competing theories because TAM aims to enlarge the model to accommodate changing ICT settings [236]. Which TAM version is now recognized is uncertain because there are several different versions of TAM and because TAM is based on several different collective models and theories of individual behaviors and perceptions [237]. To improve the model's utility, it was suggested that adding extra variables to TAM that reflect social and human elements [238].

Table 2.6 is a summary of the three key theories identified to be relevant to the proposed research and how each of them is important to the research objectives. Rogers Diffusion of Innovation theory is considered relevant to all the objectives of this study, Task Technology Fit Model is considered relevant in objective 1 and Technology Acceptance Model (TAM) is considered relevant in Objective 3 and 5

Table 2.3: Theoretical framework and Research Objectives

	Research objectives	Applicable theory
1.	identify different BIM software applications used by professionals in the building industry	Rogers Diffusion of Innovation Theory/ Task Technology Fit Model
2.	examine the awareness level of BIM uses across building stages in the Nigerian building industry.	Rogers Diffusion of Innovation Theory
3.	evaluate the level of usage of BIM across the building stages in the Nigerian building industry	Rogers Diffusion of Innovation Theory/Technology Acceptance Model.
4.	identify factors that influence the adoption of BIM in the Nigerian building industry.	Rogers Diffusion of Innovation Theory
5.	analyze the significant BIM benefits in the Nigerian building industry.	Rogers Diffusion of Innovation Theory/Technology Acceptance Model.

Source: Source: Researcher's Summary from Literature Review, 2023.

2.3 Review of Empirical Studies

2.3.1 Comparative Review of BIM Adoption: Global Context

Around the world, there are several inquiries and studies on BIM creation and use. A study created a global map of BIM adoption; Africa is the only continent that has not been assigned a value for adoption [239]. This is ascribed to industry confusion, a dearth of credible studies, and a low degree of BIM implementation in African nations. Lessons were planned to be learned at the country level, specifically their respective adoption trends, in this perspective. Several countries around the world have been working to safeguard the digital transition; for example, the United States, United Kingdom, Australia, Singapore, South Korea, Denmark, Russia, and Finland, to name a few.

Some bodies survey the BIM adoption and provide NBPs from many of these countries, to maintain guide and keep track of the BIM progresses. BIM Innovation Capability Programme (BICP) –Ireland; National BIM Reports by National Building Specifications – UK; NATSPEC –Australia; and Smart Market Report by McGraw Hill Construction – USA are some of the bodies. For a comprehensive assessment of BIM adoption and its business value, McGraw Hill Construction remains the only source of NBPs [240].The social aspects of BIM adoption, including readiness, awareness, adoption level, capabilities (stages), as well as impediments and motivators for adoption and implementation, have been the subject of several recent academic discussions [241]. These initiatives (by nations and organizations) have had a big impact on how the BIM adoption process was revolutionized.

According to research done to assess the business value of BIM in the US, the adoption of BIM increased significantly from 28% in 2007 to 48% in 2009 to 71% in 2012 [242]. Further study looked at North America in five different regions: The West, Midwest, Northeast, South, and Canada; noting that the West of North America had the highest level of BIM adaptation (77%); Canada was second at 72%; and nearly half (49%) of BIM users in the US had five years or more of experience [243]. 46% of US infrastructure projects were employing BIM, and 73% of those projects said they had only recently begun using BIM. The research revealed that BIM usage has increased significantly over the past four years, however, infrastructure projects have lagged behind vertical construction projects by three years in adopting BIM. A similar study was undertaken to determine the business value of BIM in

Europe. According to this study, more than one-third of the industry in Western Europe (UK, France, and Germany) have used BIM. Architects were the most likely to adapt, at 47%, followed by engineers (38%). One-third of participants said they had more than 5 years of BIM experience, compared to almost half (18%) of those in the US. Despite having almost similar levels, France led in BIM adoption with 38%, followed by Germany (36%), and the United Kingdom (35%). Engineers were the first to embrace BIM in France [244].

The UK Government's BIM policy has placed a special emphasis on measuring BIM knowledge and utilization in the UK construction industry. It has also identified specific targets and areas for expansion. Similarly, the National Building Specification (NBS) produced its first BIM report in 2011 to assess the UK's stance toward BIM. According to the results of this poll, 43% of respondents were not aware of or used BIM. The percentage of respondents who utilized BIM was 32%, and the percentage who expected to use BIM within the next year was nearly double (62%) [245]. In addition, the results of the 2011 BIM Survey conducted by the Quantity Surveying and Construction Information Technologies Business Group and the RICS BIM Steering Group show that 56% of Quantity Surveyors and Building Surveyors in the UK utilize BIM on average. Nearly a quarter of the participants (23%) said they used it "infrequently or in limited fashion". The majority of respondents—47%—said they did not monitor the advancement of BIM tools and processes to adopt BIM. Similarly, the Construction Sector Network (2012) indicated that 57% of UK construction companies were using BIM, and 56% of these companies appeared to have been using BIM for more than four years.

Furthermore, a survey was undertaken in 2012 by the National Federation of Builders to gauge the UK's contracting industry's level of BIM readiness. Findings revealed that only 36% of contractors had ever worked on projects utilizing 3D drawings, clash detection tools, schedule integration tools, or other BIM features, despite almost half of them (48%) viewing BIM as a crucial concept that will enable core competency within their businesses now or in the future. A comparable survey was conducted in the Middle East to aid in the regional planning and development of BIM programs and infrastructure. This poll included a wide spectrum of experts from various industries working in the United Arab Emirates, Saudi Arabia, Qatar, Oman, Bahrain, Kuwait, and Jordan. According to research findings, the region's BIM utilization rate was 25%, which is considered moderate but not extremely low when compared to the BIM usage rates in the US (49%) and Europe (36%) respectively. The assessment said that while the area knew about BIM, it lacked experience. The three main advantages most frequently mentioned by BIM users were a decrease in design errors, increased productivity, and greater quality control. The primary barriers to BIM adoption were determined to be a lack of qualified employees and the high cost of the software. According to the research, the Region would have an adoption rate of 80% and implementation rate of 90% in 2025 [246].

A study identified the barriers to BIM adoption and ranked them according to relevance. This study provides valuable insight into the UK BIM adoption strategy and, more significantly, points out the biggest challenges so that adopters may focus more on them [247]. However, removing one or more obstacles without eliminating all of them won't put an end to the problems with BIM adoption.

In the NBS research from 2018, there are two categories of hurdles to BIM adoption: internal (i.e., a lack of training, knowledge, and investment capital) and external. A study collated the most recent hurdles and, for the simplicity of the analysis, divided them into five categories: human, legal, management, cost, and technical. 22 gathered adoption hurdles for BIM were taken from 62 publications. That does not necessarily hold for all professional sectors, organizations, or even nations as a whole. For instance, the UK reported 18 hurdles in their continuous BIM evaluation survey [248] however, these are not the same barriers that Sun, [249] extracted. The lists do have several features and terminology, though. For instance, it was observed numerous obstacles to BIM adoption across the UK and claimed that these obstacles frequently stem from organizational preparation [250].

2.3.2 Review of Studies on BIM Diffusion and Adoption in Nigeria and Other Developing Countries

Although both developed and developing countries continue to face challenges, the developed countries are ahead thanks to the efforts of certain governments and institutions [251]. The deployment of BIM has not yet reached the desired level [252]. BIM's slower rate of adoption in developing countries was found to be due to a lack of government support and knowledge, a lack of implementation guidelines or methods, and a high cost of implementation [253].

According to a study, the adoption rate of BIM is only 30% in the Middle East and is only slightly higher in Africa [254]. Also, Kenya's construction industry is still falling behind in adopting BIM, which has resulted in subpar information management and project stakeholder coordination [255]. Only 13 percent of the 268 participants from private and public organizations in Malaysia, had adopted BIM [256]. This issue was attributed to low awareness, sluggish acceptance, and unclear policy guidelines. Malaysia.

In Nigeria and other African nations, few studies have examined the adoption and use of BIM [257, 258]. Like most developing nations, the Nigerian building industry is considered to be in its infancy when it comes to BIM [259, 260]. This is true even though Nigeria has West Africa's largest construction industry [261]. BIM adoption in Nigeria is low despite a good level of knowledge. A survey conducted found that 32.6 percent of the total respondents were aware of BIM technology. The respondents were asked to respond Yes or No on their awareness of BIM technology [262].

The only project in which BIM is implemented fully i.e from conception to construction stage in Nigeria is the Eko-Atlantic City project which commenced in 2010 and is still ongoing. The project is aimed at restoring land lost to coastal erosion over the last century. It is a public-private partnership-based type of project between South Energy X and the Lagos Government. It uses an information-sharing platform referred to as Eko-Atlantic Mobile Application (EAMA) and Augmented Reality (AR). The EAMA is an easy-to-use application that regularly updates project presentations, featuring an enhanced virtual tour; this enables easy navigation for the users across the construction works by moving their mobile devices around [263].

The history of Eko Atlantic City (EAC) can be traced back to 2003 when the Lagos State Government was in search of the best way to solve coastal erosion problems at Bar Beach off Victoria Island. Between 2003 and 2005, efforts were channeled towards investigating the project's feasibility in solving coastal erosion problems. This gave birth to a new city with the sole purpose of protecting shorelines and providing more housing units [264]. EAC is a unique city intended to originate from the Atlantic Ocean and is being created to revamp the shorelines of Victoria Island that have been destroyed as a result of coastal erosion. The construction of the city was executed under a public-private partnership between South Energy X Nigeria Limited (SENL) and Lagos State Government. The city is aimed at making Nigeria one of the attractive tourist destination in Africa which will foster economic development. In terms of power administration, the city is categorized as its metropolis and will operate on its administration. It will likewise be a seaward financial zone and permit the free movement of capital by speculators [265].

The city is specially designed for a wide range of activities including financial, residential, tourist' accommodation, commercial, and leisure activities. Upon completion of the project, it is expected to accommodate 250,000 inhabitants and 150,000 commuters. In addition, it is anticipated to have 10 districts which include; Business Districts, Harbor Lights, Marina Districts, Downtown, Eko Island, Avenues, Four Bridges, Eko Drive, East Side Marina, and Ocean Front. The design of the city is exceptional as it encompasses independent power supply and water treatment, advanced telecommunications, a low carbon footprint, no on-street parking, an international school, and a hospital which were all included in the EAC BIM model. It was added that most buildings in the EAC project were high-rise buildings with setbacks to minimize the effect of shadows on infrastructures. Some of these buildings are named as follows; Eko Corporate Tower, Eko Boulevard, Le Reve Tower, Afren Tower, Eko Pearl Towers (Champagne Pearl, White Pearl, Black Pearl, Indigo Pearl, and Acqua

Pearl), Azuri Peninsula, Arep Towers, International School, Atlantic Business and Residence, Eko Mall, Eko Energy Estate, 3-Marinas, and Eko At- Atlantic Medical center. In terms of value, it was revealed the cost of waterfront and inner-city plots to be $2,000/ sqm and $1,000/sqm respectively while the estimated project cost stood at $6 billion [266].

A study acknowledged the vital role played by BIM in the EAC project as it ensures that all aspect of the project was fully captured without omissions [267]. BIM is a significant tool in enhancing lifecycle and knowledge sharing in the construction project [268]. Despite this importance, BIM is yet to be fully implemented in most construction projects as a study recorded a 40% level of awareness [269]. The EAC project demonstrated the significant benefits that can be derived from the full implementation of BIM in the Nigerian construction industry. Plate 2.4 – 2.9 shows some of the BIM models developed for the EAC project.

Plate 2.4: Corporate Tower
Sources: [270]

Plate2.5: Azuri Peninsula

Sources: [271]

Plate 2.6: Marina Residences

Sources: [272]

Plate 2.7: Southern Boulevard

Sources: [273]

Plate 2.8: Eko Pearl Towers

Sources: [274]

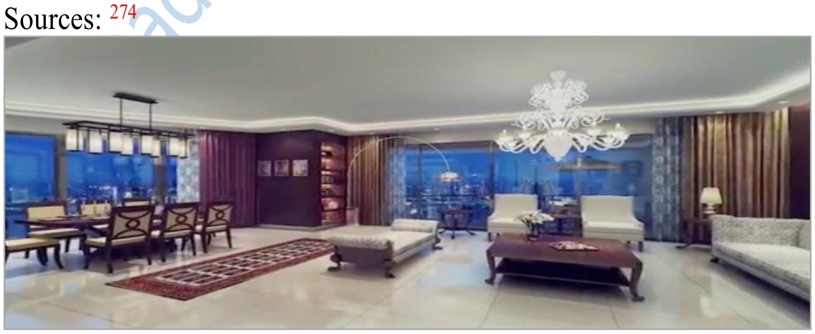


Plate 2.9: Atlantic Resort (Internal)

Sources: [275]

However, there is limited research on BIM within the study country on a general level beyond a specific discipline and or city in the country. This can be noticed in the fourteen compiled published works as seen in Table 2.9

2.3.3 Review of Studies on BIM-Compliant Software Applications Used by Professionals in the building industry

To meet the growing demand for BIM-enabled construction in the building industry, a variety of BIM-compliant software has been developed over time and is still being developed. A major player in BIM software remains Autodesk; as the industry's first producer of BIM software, they have remained in the lead in terms of software products to be used in BIM [276]. Among the software produced by them are Autocad, Revit Architecture, Autodesk Quantity Takeoff, and Green Building Studio [277]. Table 1 provides a breakdown analysis of the different software, including information about the software, its use in relation to BIM, professionals who frequently use it, and the BIM-related services it provides to professionals.

Table 2.4: List of BIM Compliant Software Applications

S/N	Software	Use	Professionals	Services Available
1.	Tekla Structures	Steel and Concrete Detailing, structural models	Structural, Steel and Civil Engineers	Structural Designer, Tedds, BIMSight
2.	Archicad	Architectural BIM CAD	Architects	Parametric Modelling and Design, Data Interchange, Remote Access and

				Collaboration
3.	ArchiFM	Asset Planning, Maintenance, Reporting Services	Facility Managers, Estate Surveyors	BIM Computer Aided Facility Management Software
4.	Green Building Studio	Analysis of Green Building requirement, Energy Analysis, Interoperability	Green Building Experts, Designers, Contractors and Planners	BIM-Green Building Standards Integration Module.
5.	Masterbill	Integrated CAD and BIM enabled measurement Module	Quantity Surveyors, Estate Surveyors, Project Schedulers	BIM Enabled estimating and Scheduling (4D BIM).
6.	Revit Architecture	Architectural Designs, Structural and MEP modelling	Architects, Services and Civil Engineers	4D BIM modelling and Parametric Design
7.	Skecthup	Architectural and Mechanical Design and Models, Interior design,	Architects, Mechanical and Interior Designers.	3D modelling
8.	PowerCivil	Integrated site, building and aerial planning	Design Team	Site Development
9.	Digital Project	Information Sharing and Interoperability of various CAD softwares.	Architects, Modelers, Schedulers	Architectural computer aided design
10.	Navisworks Manage	Complement 3D Design Packages, 4D Time simulation	Architects, Quantity Surveyors, Scheduler, Project Managers.	Roamer, Publisher, Clash Detective, Autodesk Renderer, Quantification, Timeliner, Animator, Scripter

11.	Autodesk Quantity Takeoff	Quantity Take-offs	Quantity Surveyors, Scheduler	3D and CAD enabled quantity taking off
12.	VICO Software	Virtual Construction, Quantity Take-offs, Project Scheduling, Cost Estimation, Production Control.	Contractors, Quantity Surveyors, Scheduler,	5D BIM Virtual Construction
13.	Bentley BIM Suite	Architectural Designs, Structural and MEP modelling,	Architects, Services and Civil Engineers	Architectural, engineering and Construction, 3D Modelling
14.	QS CAD	Quantity Take-offs	Quantity Surveyors	3D and CAD enabled quantity taking off

Source: [278, 279,280]

2.3.4 Review of Studies on Factors that Influence the Adoption and Optimization of BIM

Several researchers have investigated factors that influence the adoption and optimization of BIM in different countries. Whereas some of these factors were identified as barriers that limit adoption, some others are considered drivers or critical success factors that encourage their adoption in the building industry. These categories of studies are reviewed in this sub-section below.

2.3.4.1 Review of Studies on BIM Adoption Success Factors or Drivers

Research on influential drivers of BIM adoption has been extensive, but mostly discussed through a particular BIM lens of theoretical framework and neglecting the correlations and combination of different theories. It was noted that because of the particular theoretical lenses that researchers embraced, there is dispersion in the investigation of the BIM adoption drivers and variables - across many studies. For instance, a study that used the Institutional Theory to examine the influence of only the isomorphic pressures (i.e., coercive, mimetic, and normative pressures) in isolation from other factors (i.e., innovation characteristics and internal characteristics) found that the isomorphic pressures had a significant impact (INT) [281].

Another study employed the Technology Acceptance Model theory as a theoretical lens to help it investigate the effects of just two variables, namely "Perceived ease of use and Perceived usefulness," on BIM adoption (Ahmed and Kassem 2018). Therefore, all BIM adoption drivers identified from literature were categorized into three namely: BIM innovation characteristics drivers, internal environment characteristics drivers and external environment characteristics drivers which are discussed below.

i. **BIM innovation characteristics drivers**

Relative advantage

Relative advantage refers to expected advantages or perceived profits supplied by the innovation to an organization and the degree to which an innovation is viewed as being superior than the preceding notion [282]. Some researchers stated that, relative advantage is the most precise predictor that significantly contributes to evaluating the rate of innovation adoption [283, 284]. Relative advantage was first presented by Rogers in 2003. It is an important factor that drives an organization's behavioral intention to embrace an innovation and decides whether an innovation (like BIM or ICT) is relatively advantageous through the estimated benefits [285, 286].

The proportionate advantages that an innovation offers a potential adopter (such as financial gain and social standing) depend on its nature [287]. According to earlier research on innovations in the ICT/IS, relative advantage positively promotes the adoption of the innovation [288, 289, 290]. The relative advantage of some technologies, according to other studies, may not be significant across industries. Such research acknowledged issues like: unrecognized expenses, the requirement for human resources for maintenance and promotions, the potential loss of general asset control, and the low quality of the processes of the factors that affect the relative advantage of innovations [291]. Because of this, the relative advantage will prevent people from adopting innovations [292].

The positive influence of relative advantage is seen in the context of BIM adoption in the form of, for instance: economic/financial benefits (i.e., cost savings), marketing aspects (i.e., firm marketing is supported by BIM adoption), use of 4D BIM for sharing the construction plan [293], and support to various activities and processes across the AEC industry [294]. Therefore, relative advantage might show the degree to which BIM adoption is predicted to improve existing work performance [295]

Compatibility

"The degree to which an invention is reliable with a potential adopter's current values, prior experiences, and current needs" is how compatibility is characterized. According to numerous research on ICT/IS adoption in organizations, compatibility is a crucial element in the adoption of new technologies [296]. A relative advantage is given to the organization or potential user when a certain innovation, such as cloud computing, is compatible with present business procedures. According to earlier research, the perceived usefulness and simplicity of the innovation will increase the 'behavioral intention' to adopt it by increasing the organizations' existing work experience and responsibilities [297, 298, 299, 300].

Similar research has been done in the area of BIM adoption, where compatibility has been acknowledged as a key factor influencing potential adopters' behavioral intention to adopt BIM [301, 302]. According to a study, interoperability with existing workflows and processes is a requirement for organizations adopting BIM because it is believed to improve business performance and operations [303]. In this context, software compatibility can be thought of as the ability of BIM technology to enable information sharing among distinct BIM platforms. Therefore, the absence of such compatibility prevents organizations from successfully adopting BIM [304].

Complexity

Complexity is "the degree to which an innovation is seen as difficult to understand and utilize," [305, 306]. It is recognized as one of the crucial innovation traits that influences an organization's desire to embrace an innovation (i.e., its behavioural intention) [307]. When evaluating the advantages and challenges of new technology innovation, complexity is seen to be one of the most important indicators and predictions [310]. Innovation's intricacy can come in many forms. It might make it more difficult to comprehend innovation, as evidenced by the differences between low-tech and high-tech developments. It may also demonstrate the novelty (originality) of an innovation. Organizations are less inclined to adopt innovations that are more difficult to deploy and less testable because they are more unclear about their success and have a lower likelihood of boosting organizational performance [311].

Complex innovations require additional adoption management skills, such as creating an environment for innovation, integrating the innovation into current organizational procedures, maintaining awareness of resistance to allow for effective implementation, resolving opposition to innovation, and accelerating its adoption by organizational personnel [312]. Prior study has revealed that complexity is a barrier to an innovation's adoption by organizations (such as ICT/IS), as it reflects the degree of difficulty to use an innovation, which causes some uncertainty [313, 314, 315]. Similar to this, earlier BIM study found that organizations were less likely to embrace BIM when it was more sophisticated [316, 317, 318]. Therefore, an innovation's likelihood of being adopted by organizations increases with how easily it may be incorporated into business operations [319].

Trialability

"The extent to which an idea can be tested with on a limited basis" is referred to as trialability [320]. Additionally, it offers the chance to test out innovations before deciding whether to accept or reject them [321]. Such a trial shows how simple it is for a potential adopter to try the new invention [322]. Trialability has been found in earlier studies on ICT/IS innovations to positively influence the adoption process [323]. Similar to this, extensive studies [324, 325, 326, 327] have suggested that trialability is a key element that influences the decision to adopt BIM. Trialability also offers the opportunity to examine the unique benefits of BIM without bias or harm to the company's bottom line [328].

Additionally, the innovation trialability reduces uncertainty and tends to increase the adoption rate [329]. For instance, trialability offers the intention to test BIM in a limited way, the likelihood of risk reduction through testing BIM before potential adopters decide to adopt it, and the desire to determine how BIM would affect the performance of the firms by testing its features [330]. However, lack of social practice that encourages sharing of advantages and experience of BIM implementation among potential adopters' challenges trialability as an adoption factor [331].

Observability

Observability is "the degree to which the outcomes of an innovation are visible to others"(Rogers, Singhal, and Quinlan 2019). It is how evident and well-communicated the results of embracing an invention [332]. Observability and trailability are major elements that affect an innovation's adoption, according to a large body of prior research on ICT/IS innovations [333,334, 335, 336]. However, other studies have reached quite divergent conclusions [337, 338, 339, 340]. Similar contradictory conclusions have also been reached by a number of research on the adoption of BIM [341, 342, 343].

For instance, it's believed that BIM benefits are hard to see, hence observability has no bearing on whether organizations in the UK construction industry embrace BIM [344]. This is a result of the hesitation to divulge what can be thought of as sensitive and secret financial information in a market that is cutthroat. Another obstacle is the reluctance to actively endorse BIM due to the weak evidence of its influence in the AEC industry [345]. BIM observability assessment could take the form of, among other things, support for publicizing the benefits of BIM, a clear understanding of those benefits, and a desire to recommend BIM to prospective adopters [346, 347].

Technological factors

Technological variables reveal the qualities of the innovation that will be embraced [348]. In addition to social systems and communication channels, Rogers recognizes technological qualities as one of the significant variables influencing the acceptance of innovations. It's claimed that the technological elements are drawn from the "Innovation Diffusion Theory and encompass relative advantage, complexity, trialability, compatibility, and observability," based on Doolin and Troshani's (2007) study technique [349]. These elements have an impact on adopters' ideas that they can rationally choose to accept a new technology based on advantages vs. costs. Similarly, a study looked into how technological characteristics, such as compatibility and simplicity of use, affected people's decisions to adopt new technologies [350]. Frustration with the use of ICT and the influence of these elements, as measured by the supporting technology features, are factors influencing the adoption of innovation. On the other hand, earlier research on innovation (such as ICT and BIM) concentrated on both physical and non-physical aspects [351, 352, 353]. For instance, factors affecting the capacity of tools and infrastructure; BIM-based platforms for collaboration among AEC disciplines ; interoperability of software applications ; and the accessibility and cost of BIM software are just a few examples [354].

Table 2.5: Summary of BIM Innovation Characteristics Drivers

No.	Main adoption drivers	Determinants influencing BIM/innovation adoption	Study
1	Perceived	Improvement of job satisfaction, outcomes, and	[355, 356, 357]

	Usefulness	productivity by BIM	
2	Perceived Ease of Use	Convenience of BIM operation	358, 359
		Understanding of BIM interoperability and ability to implement BIM tools	360,361
		Ease of getting expected outcomes by BIM	362
		Personal recognition of ease of BIM operation	363, 364
3	Relative advantage	Productivity improvement; Overall advantageous in my job; Duration shortening; Improve of task performance speed; Effective action to risks; and More effective quality control.	365, 366
		Cost reduction/saving	367, 368, 369
		Increasing cost efficiency; Improving inventory replenishment; and Consolidating marketing strategy	
		Increasing product security	370
4	Compatibility	Ease of concurrent implementation or incorporation into existing processes	371
		Applicability to existing processes without change	372
		Compatibility of BIM with my job, and Compatibility of BIM with my work style	
5	Complexity	Expectation that works become easier by BIM; Expectation of smoother work processes by BIM; Ease of learning BIM; and Improvement of mutual cooperation in the organization	373, 374, 375
6	Trialability	Intention to try out BIM in a limited scope in my works, before deciding whether to adopt it in practice; Possibility of risk reduction with the try-out above before adopting BIM in practice; and Intention to try out various BIM features in my works to verify its effects	376
7	Observability	Proof of cost savings by its adoption	377
		Communicability, Demonstrability, Profitability, and Perceived risk	378
8	Technological factors	Interoperability among applications software; Compatibility of software; Visualisation of design effects; and Collaboration platform.	379, 380

Source: Source: Researcher's Summary from Literature Review, 2023

ii. Internal Environment characteristics

Top management support

The level of senior management's involvement in information systems activities and understanding of the function's significance can be characterized as top management support [c]. The acceptance and execution of advances in information technology and information systems are known to be crucially influenced by top management support [381]. According to a number of BIM studies, top management support is a critical element in BIM adoption [382, 383, 384]. It was also asserted that the success of the BIM adoption depends on top management support [385].

Additionally, it was found that top management support had a significant impact on how the architectural companies behaved with regard to adopting BIM [386]. In order for the organization's members to implement the change in business processes, top management support is required for the adequate provision of resources and integration of services [387, 388, 389]. It has the capacity to create an environment that is more supportive of the implementation of IT innovations, facilitating the adoption of the innovation [390].

Furthermore, employees' opinions of innovation and system usefulness increase with top management backing [391]. They won't accept it if top management doesn't support it and they don't see how the new invention will help their company [392].

Communication behavior

One of the most crucial traits of adopter categories of inventions (i.e., innovators, early adopters, early and late majorities, and laggards) is communication behavior [393]. A social system's members communicate with one another through communication channels, which is explained by communication behavior (interpersonal networks). The categories of adopters described by Rogers exhibit various communication behaviors. Innovators' social networks are typically found outside of their system, not within it. The innovators engage in activities outside of their local system and engage in extensive travel. Significant changes can be observed between earlier and later adopters [394].

Early adopters are more cosmopolitan, more socially engaged, more heavily connected to their system's interpersonal communication channels, more exposed to mass media networks, more engaged in interpersonal communication channels, more involved in effective information seeking, more knowledgeable about innovations, and more so than later adopters. They also interact with change mediators more frequently and interact with them on a more personal level [395].

According to a study, communication behavior in the construction industry "can either be formal/ intra-organizational communication (example: coworkers interacting within the same division) or informal/ inter-organizational communication (example: like-minded individuals of other organizations meeting up and sharing good examples of practice for their individual mutual advantage)" [396]. Individual concentration has a significant impact on innovation inside organizations and determines whether new procedures or innovations will be adopted by others [397].

As a result, communities of practice are organizationally more helpful for the development and uptake of novel ideas [398]. In addition, "effectiveness of information flows (communication flows) within organizations; strength of relationships with other parties (clients, governments, labor unions); learning from external sources; and interactions between individuals and organizations within the construction industry and between the industry and external parties are examples of communication behavior" [399].

Financial resources

The "money accessible to a business for expenditure in the form of cash, liquid securities, and credit lines" is known as financial resources. It refers to "the extent of financial resources that are readily available for the project" [400]. When implementing technology and making decisions during the BIM adoption process, it is necessary to evaluate the firm's financial resources. The management of significant financial resources is helpful in preventing potential losses from an unsuccessful innovation (Rogers, Singhal, and Quinlan 2019). In this context, a study discussed the indicator of a company's financial health based on the early adopters who are best able to bear the risk associated with implementing new innovations [401].

In fact, there is a certain amount of financial resource risk when purchasing the gear and software necessary for adopting BIM, which also creates demands for staff preparation and training [402]. The organizational preparedness - as adopter characteristics - to allocate financial resources to organizational innovation refers to the adoption of an innovation (e.g., IT/IS technologies) [403, 404, 405]. The choice to implement an innovation should be made after a financial, technical, and strategic examination. In order to do this, adequate financial resources must be allocated for acquisition and implementation [406].(Silva et al. 2022)

The early stages of BIM adoption shown that it would be difficult to deploy BIM without widespread knowledge of its value and backing from the financial community [407]. BIM demands a large setup investment in architectural firms to begin BIM deployment in architectural projects. It is possible to divide the budget into "one-time setup costs" and "general system-related costs" [408]. The one-time setup fee includes all expenses necessary to provide the technical components and organizational solutions [409]. While the general system-related cost includes all costs associated with the system's assembly and the organization's preparation for the BIM process. According to general belief, innovations with lower financial costs are more likely to be embraced by organizations [410].

Organisational readiness

Organizational preparedness is "a multi-level and multi-faceted concept" that refers to organizational members' shared commitment to carrying out a changing duty and shared faith in their collective ability to do so (change efficiency) [411]. Organizational preparedness is the period of planning and preparation before an organization implements its first BIM capabilities [412]. A company's level of "readiness" for BIM innovation is indicated by this term [413]. The proactive planning a corporation makes for the invention is necessary for the innovation to be adopted successfully. A crucial critical success element for IT/innovation adoption intention has been highlighted in prior studies as organizational preparedness [414].

For instance, a study investigated three organizational preparedness factors: technology expertise, senior management support, and financial resources. IT infrastructure, innovation champions, and top management support were all the subjects of a 1995 study by Premkumar and Ramamurthy [415]. Other organizational readiness traits, such as centralization, company size, formalization, specialization, and complexity, are also examined in IT adoption studies [416]

Social motivations

"An incentive or drive originating from a sociocultural impact that initiates behavior toward a certain objective" is what social motivation is [417]. In contrast to economic reasons, a study looked at the positive effects of proactive image motives and reactive motives on BIM adoption procedures within organizations [418]. Reactive motives passively conform to the external environment, while image motives actively uphold the respectable image of integrating cutting-edge technologies (e.g., complying with BIM needs from governments, and promising to enhance competitiveness by employing BIM). BIM as a socialized innovation process can be challenging because of institutional pressures [419].

As a result, external forces change social motives and organizational awareness into a crucial component when forming the adoption and implementation procedures [420]. Organizations usually acknowledged that social incentives were a crucial consideration when deciding whether to embrace technology [421]. The process by which individuals make decisions and the environment in which they are made combine to produce organizational adoption decisions [422]. The crucial function and influence of social motives in knowledge sharing among employees in construction organizations were described in a study by [423]. It included procedures that mirrored management behavior, adherence to culture, peer recognition, reciprocity, and keeping promises.

Previous BIM/IT study identifies factors that influence how social motives influence organizations' adoption decisions. Examples include encouraging people to adopt BIM and managing resistance to BIM change; perceptions and attitudes toward the type of innovation; managers interpreting social influence based on perceptions rather than concrete understanding of the real world; positive/negative feelings and emotions toward IT use; and product quality [424]

Organisational culture

The term "organizational culture" refers to the conventions, principles, traditions, and ideas that all members (i.e., employees) of an organization practice or organizational unit hold in common and which aid in the members' comprehension of how the organization functions (Lin 2021). These shared values provide as clear guidelines for employees' intra-organizational behaviors and attitudes as well as their expected inter-organizational code of conduct [425]. Supply chain management strategies and the adoption of new IT/IS are thought to be significantly influenced by organizational culture [426]. Companies are more likely to accept an innovation (such an information system) if the system's norms and values align with their organizational culture [427].

Additionally, a company exercises caution by adhering to its own unique ideals and attributes rather than passively accepting the widely accepted traditions in its organizational sphere [428]. In this line, a study examined how institutional forces and organizational culture interact to affect firms' intentions to adopt innovations while taking into account how the organizational culture modifies these impacts [429]. The social acceptability of BIM (i.e., behavioural acceptance) from the perspective of architects can be explained by the need for organizations to have an environment and organizational culture that are more favorable to the deployment of BIM. By doing this, organizations will succeed in their goal of raising staff and employees' perceptions of the value of BIM, which leads to effective BIM implementation [430].

Willingness

One of the key elements influencing the adoption of innovation (such as BIM and ICT) is willingness [431, 432]. Potential adopters (i.e., retailers) must be aware of the investments made by providers to gauge their commitment to and desire to invest in inter-organizational technologies. At the organizational level, relative advantage and technological complexity are the two key determinants of whether businesses are willing to adopt new technology [433]. In this regard, a study identified compatibility, subjective norm, and top-management support as the major determinants of architects' behavioral willingness and intention to use BIM. The perception of risk-reduction metrics, perceived hazards, and individual participation all have an effect on people's readiness to accept new technologies [434].

According to Fox and Eze et al. (2019), it may be difficult to reap the benefits of BIM if there is a lack of experienced personnel who are proficient in both ICT and construction. Lack of appropriate training results in the loss of the advantages of implementing new technologies. Consequently, one crucial aspect of the deployment of BIM is training [435]. The value of BIM adoption is therefore thought to mostly depend on BIM technological proficiency training, and when well-trained personnel believe that BIM is simple to use, they tend to demonstrate more desire to deploy BIM than untrained staff [436]. Therefore, potential adopters may be prepared to employ a new innovation if it can increase efficiency, is simple to learn and use, and they see less risks and more rewards associated with adopting the new invention. Learning interest is influenced by attitude. People will embrace BIM more happily and successfully when they are not intimidated by the complexity of a technology [437].

As a result, the perceived advantages (useful investment and risk reduction) and perceived usability of an invention impact the organizational behavior desire and intention to adopt it (ease of learning and training). The available BIM/IT literature identifies factors that influence organizations' adoption decisions, such as business interest, stakeholder interest in learning BIM and willingness to use BIM, the need for innovation, innovativeness, and the diffusion of innovation, incentives and enjoyment with innovation, and competitive advantages in the market [438].

Organisation size

The beneficial function of organization size in innovation adoption has been extensively discussed in literature [439, 440, 441]. The role of organization size in the acceptance of innovations, however, has been the subject of repeated debate in the literature on organizations [442]. Numerous studies examined the relationships between firm/organization size and innovation/the adoption of new technologies, as well as some of the contentious issues that surround these topics [443, 444, 446].

For example, a study investigated the relationship between organization size and innovation by distinguishing between the integration of radical and incremental technologies; so also a study discovered disparities between simple and complicated ICT (i.e., internet technologies) when studying the impact of organization size on technology adoption; and Jung and another investigated the mediating role of organization size among them resulted in numerous associations based on organization size that affect the influence on the organizations' innovation adoption objectives [447, 448].

Table 2.6: Summary of Internal Environment Characteristics

No.	Main adoption factor	Determinants influencing BIM/innovation adoption	Study
1	**Top management support**	Senior management support (internal motivations to actively embrace innovative technologies such as BIM)	[449, 450, 451]
		Level of bureaucracy (for BIM adoption decision-making)	
		Corporate/project leadership style (democracy/autocracy)	
		Centralization; CEO innovativeness, attitude, IT knowledge, and involvement; and Managers tenure, age, and educational level.	
2	**Communication behaviour**	Effectiveness of information flows (communication flows) within organization; Level of internationalization; and Strength of relationships with other parties (clients, governments, labour unions)	[452, 453]
		Demographic factors	
3	**Financial resources**	External integration	
		Learning from external sources	
		Outsourcing	
	(Perceived cost)	Cost of implementation	[454, 455, 456]
		Financial resources of organization	
		Selection of approach for building BIM model using in-house resources or outsourcing	
		Cost plan duration, Construction cost, Design change cost, and Construction duration.	
		Financial resources devoted to IT technologies	
		Financial perspective	
		IS investment	
		Perceived cost	
		Project-based and Cross-project economic motives	
4	**Organizational readiness**	The adopters' positive experiences and ability to adapt the technologies to successfully sustain and/or enhance business competitive advantages	[457, 458, 459]
		Professional BIM technology training	
		Training and support	
		Human capability/resources (retention of best people); and	

		Innovation capability Organizational learning capability (feedback of good practice) Technical competence of staff Technological capability of organization Research and development capability of organization Risks associated with bidding BIM projects (types, size, teams, locations) Availability and effectiveness of operations system (products and services), human resource/maintenance system (for keeping the best people), quality assurance mechanism, of marketing and sales system, procurement system (inbound logistics), and managerial system (e.g., administrative system) IT intensity and integration between functional areas of the company	
5	**Social motivations:**	Individual and group motivation for BIM adoption; Need for process reengineering for BIM; Managing people resistance to BIM change; and Socioeconomic conditions Perceptions and attitudes Subjective norm Attitude towards the type of innovation (IT) Social influence (managers capture social pressure based on their perceptions rather than an actual understanding of the real world	460
6.	**Organisational culture**	Enabling environment Organizational flexibility/adaptability to market Corporate management style (family owned or public owned) Supervisor and organisational support Control orientation	461
7.	**Willingness/intention**	Interest in learning BIM Need for BIM personnel and training, and Need to change in organization characteristics for BIM	462, 463

Source: Source: Researcher's Summary from Literature Review, 2023

iii. External Environment Characteristics Drivers

Coercive Pressures

The formal and informal constraints exerted on organizations by other organizations on which they depend are referred to as coercive pressures [464]. One of the "three isomorphic pressures" (i.e., coercive, mimetic, and normative pressures) in the Institutional Theory proposed by DiMaggio and Powell is coercive pressure. Companies are compelled by such forces to implement comparable organizational procedures and practices [465]. These legitimacy-based motivations (i.e., coercive pressures) originate from institutions in an organization's environment that create policies directly that an organization must follow and that are authoritative enough to particularly reward compliance or penalize noncompliance [466].

These institutional pressures can have an impact on an organization's structure, environment, and behavior; they also encourage an organization to adhere to institutional and political legitimacy in order to maintain its position in a social network [467]. These organizations use their power to force businesses to engage in particular activities, directly enforcing limitations on businesses [468]. Companies that use coercive coercion include, for example, buyers of large percentages of a company's output, suppliers of limited resources, and governmental and regulatory agencies [469]. If a dominant network member favors an innovation (like eSCM), that member may force its partners to accept the innovation [470]. In this process, a dependent organization would initially notice coercive factors that highlight the strength asymmetries before better understanding the effects of embracing or rejecting the innovation (i.e., eSCM). Due to its dependence on the powerful partner, the dependent company's existence may be at jeopardy if its interests conflict with those of the powerful organization. As a result, the dependent enterprise is more likely to agree to the demands of the dominant partner and to implement the innovation. So also, the organization with a control orientation would probably implement the innovation.

Furthermore, when an organization recognizes a high level of coercive coercion, its powerful partner/client assigns members of the community to organize supply chain operations. In comparison to its low control orientation peers, a high control orientation organization is more likely to enjoy the excessive implementation benefits that construct a more favorable attitude toward innovation adoption. Because of the potential benefits of BIM, governments (or their related organizations) in several countries have established plans for mandatory use of BIM in public projects. These legal activities, whether as a public rule or a project-specific need, may have a significant impact on the BIM adoption behaviors of both venture customers/owners and other stakeholders, resulting in a higher degree of undertaking .

Mimetic Pressures

Mimetic pressures arise primarily as a result of an organization's observation of the success of competitors' efforts [471]. Mimetic pressures are defined as forces resulting from behavioral confusion about how to approach a certain issue, carry out a specific activity, or achieve a specific goal [472]. Because of this ambiguity/uncertainty, an organization (i.e., company) imitates the behaviors of a seemingly successful organization within the organization's surroundings [473]. In this context, 'uncertainty' happens when a company lacks the necessary information to address a situation.

As a result, the firm feels other organizations in its environment have successfully addressed similar difficulties and, as a result, prefers to gauge its behavior by that of peer firms. As a result, it imitates organizations that appear credible and progressive. Usually, decision-makers in organizations think that a behavior of other, comparable organizations is easy to imitate since the likelihood of gain seems to be larger if such behavior has been successfully carried out in the past. Therefore, it is likely that businesses would copy other businesses that operate in similar marketplaces, make use of equivalent resources, or provide similar goods [474].

Therefore, actions taken by comparable businesses are viewed as appropriate for a business that engages in imitation [475]. A study found a statistically significant positive link between the choice to use BIM and the mimetic pressures [476]. This conclusion is based on how unique BIM is in comparison to other advancements. BIM applications typically include more complex organizational interchange and procedure in construction projects. Additionally, the costs associated with BIM are rather substantial [477].

In addition, such characteristics may materially enhance the adoption uncertainty of BIM and, as a result, push firms' decision-makers to be more effectively influenced by the direct behavior of counterpart organizations with similar characteristics and institutional environments. As a result, this influence may be experienced by all project owners and other stakeholders. In order to become better risk-averse against the relevant threats that are only partially accepted by the early adopters, clients/owners typically copy the successful actions in parallel organizations. This will prevent those clients from falling behind their competitors and so compromising their credibility [478].

The influence of mimetic pressures on the intentions and behaviors of innovation adoption decision has also been examined in some earlier research on other construction innovations, which has produced somewhat contradictory findings (Faullant 2022). These inconsistent results may be reasonably explained by the variances in the nature of such creative activities. Due to the widespread industry enthusiasm for radical and complex technologies (like BIM), the adoption decision process typically comprises not only organizational reorganization, relatively large investment costs, and intangible gains, but may also apply substantial social effects. When compared to other innovations that have a lower ROI, social impact, and degree of uncertainty, those inventions tend to be more easily influenced by the actions of peer rivals [479].

Normative Pressures

Normative pressures are the factors that result from the shared values and norms of network members, professionalization, and group aspirations within certain organizational contexts that define appropriate and lawful behavior [480]. Through knowledge transfer activities (e.g., formal education, industry associations, conference interaction, professional sessions, and workshops), these behaviors and attitudes can spread and be strengthened within professional domains [481]. The organizations that use normative pressures differ from those that use coercion in that they lack the authority to compel conformity and penalize non-compliance directly (i.e., in a less coercive manner) [482]. As a result, normative constraints do not intimidate organizations; rather, they cause them to comply as decision-makers acknowledge their own unique industrial and professional underpinnings [483].

Consecutively, persons in charge of making decisions believe that adhering to common standards established by professional and industrial organizations is beneficial for their own business [484]. Being surrounded by such professional domains may help firms gradually improve their views of widely held beliefs and values, and as a result, change how they operate in accordance with their unique organizational characteristics [485, 486, 487]. Technology providers, industry experts, and academic institutions can also impose normative pressure on industry practitioners through a variety of networks, including formal education, professional accreditation, and industry conferences.

Moreover, owners and clients may become potential deciding elements of such normative pressures because they are key decision-makers in the implementation of BIM in construction projects. Through working together with the specialists, those clients/owners may be better able to understand the industry requirements for the deployment of BIM in their specific activities. They thereby put additional pressure forone adoption of BIM. This support would result in a greater degree of BIM adoption along with the changing attitudes and behaviors of other project contributors, who might also be instantly exposed to external normative constraints [488]. Table 2.4 shows the synthesized and reviewed drivers from the literature and theoretical lenses from which they are explained. The drivers are categorized into technology context, external environment and internal environment.

Table 2.7: Summary of External Environment Characteristic Drivers

No	Main adoption factor	Determinants influencing BIM/innovation adoption	Studies

1	**Coercive pressures/ forces**	Client's willingness to adopt new technology	489
		Policy factors	490
		Pressure from competitors and peer association in market	
		An Evident push from governments to expedite the BIM uptake	491
		Clients/owners support	492
		Initiatives for changes due to the needs of sustainable design and construction	493
		BIM mandate	494
		Government promotion	
		Government financial support and subsidy	
		Regulation, policy & industry standards	
		Clients' interest in the use of BIM in their projects	
		Cooperation and commitment of professional bodies to its implementation	
		Government support and policy through legislation	
		Influence from partners who have adopted BIM	
		Formal and informal pressures exerted on organizations by other organizations or governments	
		Multi-disciplinary association pressures	
		Externalities that affect practitioners' attitudes	
		Government Mandate	
		Dependence on parent company	
		Professional bodies encouragement	
		Refusal to deal	
2	**Mimetic pressures/ forces**	Mimicking behaviours by imitating successful practices/competitors in the market	495, 496, 497, 498, 499, 500
		Best practices for Constructability Implementation.	
		Environmental Uncertainty	
		Industry associations' practice, and Main competitors' actions	
3	**Normative pressures**	Availability of BIM professionals	501, 502, 503, 504, 505, 506
		Professional BIM technology training	
		Awareness of the technology among industry stakeholders	
		Shared norms and collective expectations diffused through information exchange activities (formal education, association participation, conference communication, and professional consultation).	

Source: Source: Researcher's Summary from Literature Review, 2023

2.3.4.2 BIM Adoptions Barriers/ Limiting Factors

The advantages of BIM and accompanying productivity increases are well known, and they are increasingly more obvious as the industry develops its use of technology and processes [507]. The industry's adoption of BIM is, however, being slowed down by difficulties that arise when BIM is adopted and implemented on actual projects. BIM has been dubbed a "disruptive technology" [508] because it has the potential to significantly alter current working procedures, procurement tactics, legal and contractual frameworks, data ownership and security, and insurance policies [509]. Then there are problems with organizational changes, the price of software and hardware, the learning curve connected with it, the unwillingness of individuals to change, and overall fear of change [510, 511]. Several authors have explored the difficulties in adopting and implementing BIM, which are primarily concerned with (1) adoption at the organizational level, (2) implementation at the process-project level, and (3) obstacles associated with technology.

Challenges with implementing BIM at the organizational level relate to changes in policy, working culture, people, and related costs. The most hidden obstacle to BIM acceptance and implementation is fear of change. When people are successful at anything, it is a psychological phenomenon that they feel at ease repeating that action. Organizations are likely to encounter opposition from people who are opposed to the change since BIM is bringing about multidirectional changes in how people work and operate [512]. Another problem is that organizations don't have documented BIM standards or workflows, institutionalized quality controls for BIM models, or globally authorized and accepted BIM-specific risk detection or mitigation strategies. Due to the lack of historical data and the ongoing collection of empirical evidence on the productivity advantages brought about by

BIM, large organizations and insurance firms are currently unable to price and write insurance policies for BIM projects [513].

The relationship between present work practices and the projected future of BIM, as seen by an organization's policies, is what determines whether BIM will be adopted at the organizational level [514]. To achieve level 2 BIM status in a few years, for instance, if an organization is currently at zero BIM level it will be a challenging task that will require significant resources, advance preparation, and dedication to the BIM implementation process [515]. The essential element in determining if BIM will be adopted at an organizational level is how much it can alter the way that work is now done. It is a frequent misconception that all current workflows, procedures, and business models must change if a firm wants to accept BIM, but this is untrue because BIM can be customized to meet the needs, allowing the transition to be more effective [516]. Although some authors have emphasized the opposite, saying that the adoption of BIM necessitates considerable modifications to present business procedures at every level inside an organization [517, 518].

Process-level BIM adoption challenges are related to information transfer bottlenecks, a current lack of parametric content for significant project vendor products, unfamiliarity with BIM's breadth of ability and associated programming experience, and a lack of understanding of interoperability limitations and abilities [519]. Furthermore, it was argued that the influence of BIM on present project management methods and processes cannot be achieved without equivalent changes in the organizations and skill sets of project participants [520]. It was emphasized that the importance of redefining project responsibilities in the current network of construction projects, from top management to the bottom line supplier chain, to meet the BIM process management requirements [521].

Finally, product-level BIM adoption presents significant technical obstacles connected to the development and application of BIM technology in projects [522, 523]. The introduction of BIM in the construction sector is sparked by a completely new wave of technology, and many organizations regard it as nothing more than a collection of software programs. The BIM technology itself is maturing and becoming more purpose-fit as are its applications in real-world scenarios. Some experts have stated that, while BIM technology is widely available, the most significant barrier to mainstream BIM implementation remains [524, 525]. In addition to software and hardware restrictions, these technological challenges include the need to acquire, study, and educate new technology to assist the BIM implementation process, such as online portals, geographic information systems, etc. The requirement for interoperability and integration of BIM software programs and data structures throughout the whole life cycle of BIM projects is well-acknowledged among construction researchers [526].

For the convenience of analysis, all of the above-explained barriers to BIM implementation can be further classified into five categories: Technology, Cost, Management, Personnel, and Legal. These categories include 19 sub-factors, which can be seen in Figure 2.9.

Technological Factors

The BIM-based software packages are also called BIM tools. The technological factors refer to BIM tool-related factors limiting the application of BIM, such as imperfect or immature BIM software, a lack of standards and protocols, etc. The restricted capabilities of BIM-based software are the main factor limiting its application in the AEC industry. For instance, the lack of scalability, interoperability, and support for remote collaboration, and its unsuitability for the production modeling of cast-in-place (CIP) reinforced-concrete structures are the biggest constraints on the mainstream application of BIM [527], Interoperability is defined by as "the ability of two or more systems or components to exchange information and to Use The Information That Has Been Exchanged" [528]. `

Cost Factors

These major costs referred to in the literature include buying the BIM-based software and hardware, the software service charges, and training costs, etc. Cost factors refer to the money-related limiting factors in the process of BIM application [529].

Management Factors

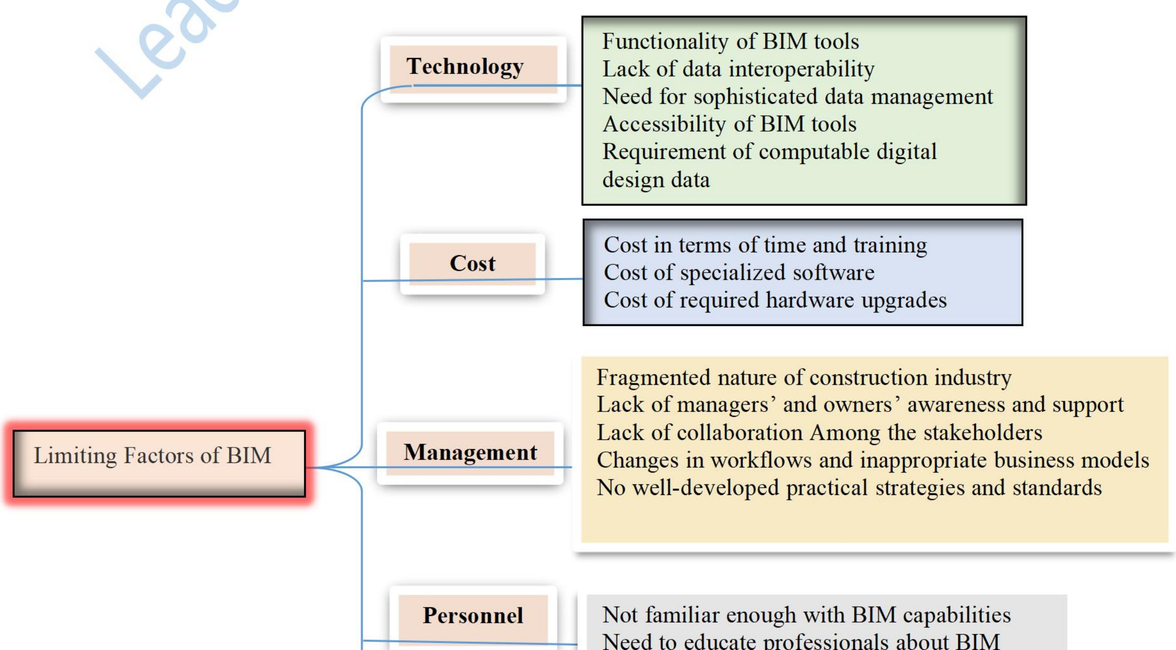
Management factors refer to the process and organization-related limiting factors, and include participants' attitudes toward BIM applications, the lack of existing successful cases and management standards for reference, the fragmented nature of the construction industry, the inappropriate business models, and the lack of cooperation from other industry partners. BIM breaks down the traditional boundaries between firms and enables the sharing of project data in a more collaborative environment [530]. This means that participants must relocate their roles in the project team and change the workflow of their companies according to the requirements of the BIM application. The changes in everything from file management to client billing, to deliverables, to coordination meetings are multifarious and complicated, and organizations need time to adapt to these changes [531].

Personnel Factors

Personnel factors refer to the professional-related limiting factors. The lack of experienced personnel who are familiar with BIM and have experience using it is another prominent limiting factor. The training and education of large numbers of professionals is necessary for the wider and better application of BIM. Even in design companies, most designers hesitate to use BIM because of the low efficiency, habitual resistance to change, and heavy work demands encountered during the initial period of setting up BIM tools [532].

Legal Factors

Legal factors refer to the limiting factors caused by the immaturity of contractual/regulatory environment. Legal and insurance ramifications usually caused by imperfect software can result in lawsuits [533]. Building information models are usually created by different professionals with various software programs and used by different participants. If significant losses occur because of the incorrect use of building information models, claims will become very complicated due to the blurred responsibility.



2.3.5 Review Studies on BIM Benefits

At every point of the project life cycle, BIM adoption has a great deal of potential to be beneficial [534]. This technology can be utilized by the owners to comprehend the needs of the project, by the design team to evaluate, create, and develop the project, by the contractors to manage the project's construction, and by facility managers during the stages of operation and decommissioning [535]. The use of BIM has been demonstrated to be a very effective strategy for decreasing uncertainty and increasing the effectiveness of the construction process [536]. BIM will enable the quick analysis of various scenarios related to the life cycle performance of a building, which could result in positive project outcomes [537] it was also asserted that BIM is particularly beneficial in boosting the quality of schedule and pricing information throughout the project lifecycle; greater utility and speed are two of the most commonly noted advantages [538].

A study in Malaysia identified a number of significant BIM benefits, including: (1) improving productivity and efficiency; (2) estimating the time and cost associated with design change; (3) eliminating design clashes; (4) improving multiparty communication and maintaining synchronized communication; (5) integrating construction scheduling and planning; (6) identifying time-based clashes; and (7) monitoring construction progress [539]. Another study highlighted 12 advantages of BIM deployment in Hong Kong [540]. They discovered that the biggest advantages are better cost estimates and control, a better understanding of design, a reduction in construction costs, better planning and monitoring of the construction process, and an improvement in project quality. A study evaluated 12 BIM benefits in Vietnam; the top five important benefits were as follows: (1) Better collaboration; (2) More accurate data from a data-rich asset; (3) Automatic model updates; (4) Improved Interoperability; and (5) Greater Productivity and Efficiency of Employees [541]. Another study identified 41 advantages of BIM adoption in Turkey [542]. The main advantages are: (1) timely task and responsibility planning; (2) encouraging collaboration and coordination in the early design phase; (3) automatic incorporation of design changes into 3D CAD model; (4) lowering uncertainty in the processes by identifying risks; and (5) minimizing time variances in the processes. In order for any new technical improvement to be successfully adopted and its benefits to be realized, including BIM, it is typically necessary to identify and address the issues that may affect the acceptance by project stakeholders [543]. Finding BIM's advantages in building projects is crucial to promote its adoption.

As a result, multiple academics from various nations have recognized and categorized distinct benefits of BIM use in AEC projects. Table 2.8 provides the most significant benefits of BIM adoption in construction projects from prior studies.

Table 2.8: Summary of Selected BIM Benefits

S/N	BIM Benefits	References
1	Improve design	[544]
2	Better clash detection	[545]
3	Better coordination	[546]
4	Reduce rework in construction	[547]
5	Better synchronization	[548]
6	Better projects sequencing	[549]
7	Give room for more off-site materials/components prefabrication	[550]
8	Enable visualization of the built environment	[551]
9	improves health and safety	[552]
10	Facilitate equipment and asset maintenance and management	[551]
11	Provides a digital model that can be utilized throughout the building life cycle	[544]
12	More accurate and speedy estimation of project cost and time	[544]
13	Improvement in energy efficiency	[546]
14	Improve resources planning and sequencing	[545]
15	Effective management of project resources procurement and storage	[548]
16	Improve efficiency and productivity	[549]
17	Improves decision-making in the operation and maintenance of a facility.	[543]
18	Access to information is fast and reliable	[545]
19	Provision of accurate and updated information	[546]

20	Improve multi-party communication and collaboration	547
21	Monitor and track progress during construction	542
22	Improve services delivery	544
23	Project cost reduction	543
24	Reduced construction time	542
25	Improve quality	539
26	Improve project documentation	549
27	Minimizes disputes and conflicts	545
28	Minimize errors and mistakes	549
29	Improving team building skills	552

Source: Source: Researcher's Summary from Literature Review, 2023

2.4 Conceptual Framework

The theories and models reviewed helped in describing the processes involved in the adoption of BIM by individuals and organizations. They also provide a comprehensive understanding of factors and drivers of BIM adoption. The conceptual framework of the study is thereby hinged on Rogers Diffusion of Innovation Theory, Task Technology Fit Model and as well as Technology Acceptance Model. Figure 2:11 gives a graphical representation of the conceptual framework for this study.

This study was based on the assumption that adoption of BIM as collaborative tool can be examined by assessing the knowledge of firms in the building industry on various BIM compliance software applications and their usage. It was also assumed that the usage of these software applications are driven by certain factors which could be drivers or limiting factors. These factors form the basis for decision making for the adoption of BIM.

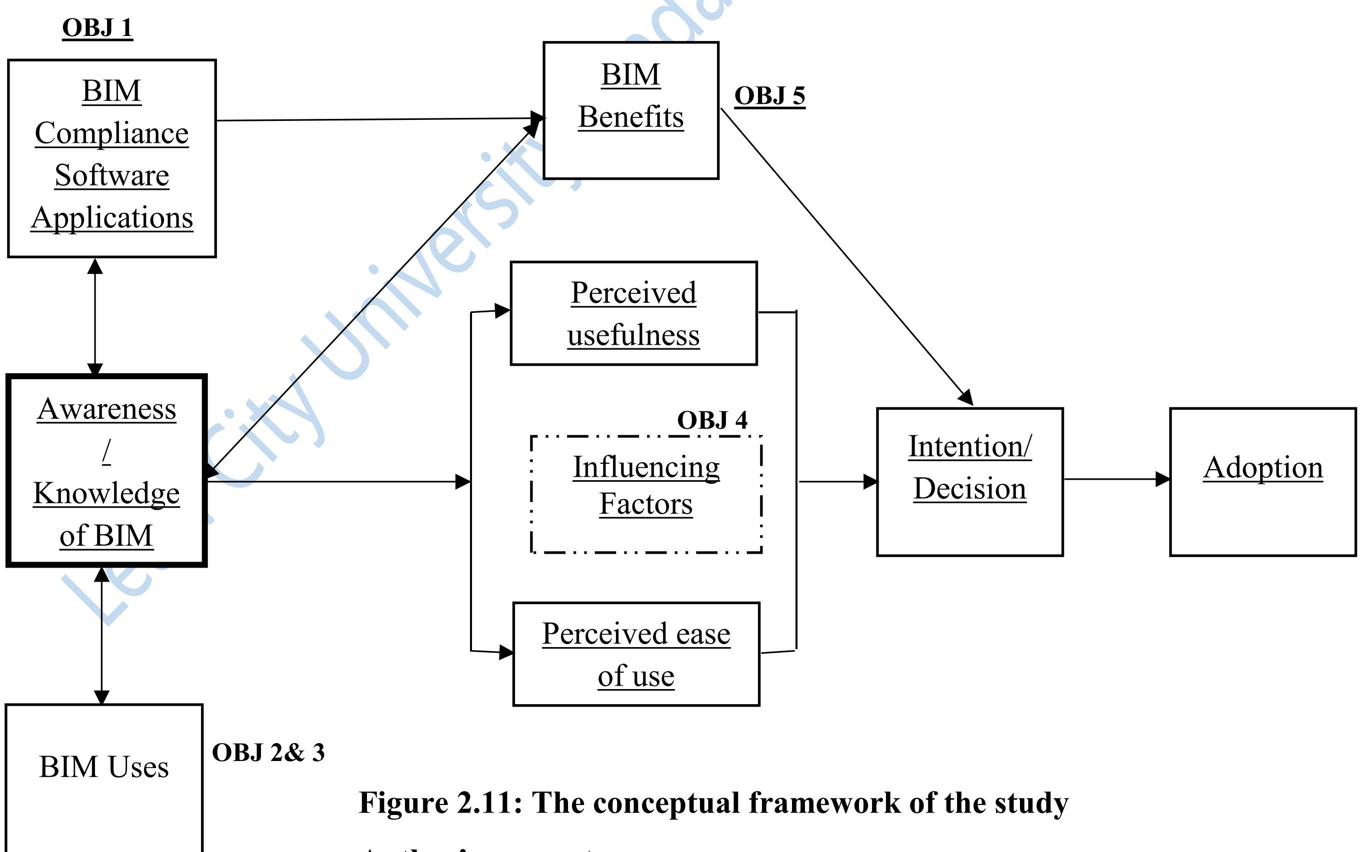


Figure 2.11: The conceptual framework of the study

Author's concept

2.5 Summary of Gaps Identified in Literature

Literature search has revealed a mass of research in the field of Building Information Modelling across countries. Some studies have helped in the identification of BIM adoption in the AEC industry towards the elimination of construction challenges, BIM software-compliant applications, factors that influence its adoption, as well as barriers limiting its adoption. Some works have also identified benefits that can be derived from the adoption of BIM. This section highlights gaps that were identified through the review of existing literature on BIM adoption.

Firstly, it was observed that a comprehensive assessment of BIM adoption in Nigeria is growing over time, and the same applies to its implementation [553, 554, 555]. Several findings in prior research, and just before this study commenced, none has carried out a broad evaluation of the industry nor does the combination of earlier findings do concerning its current status of adoption [556, 557, 558,]. All the previous research concentrated on trying to assess BIM within a limited profession or location [559, 560, 561]. There was no meeting point in identifying the current state of the key BIM components in terms of Technology, Process, and Policy [, 562, 563, 564]. Therefore, these limitations that were identified in various pieces of research facilitate this study. Additional research is needed to update and enable the majority to understand and adopt the new methods of working, especially in developing countries [565, 565].

Secondly, the existing studies have identified the benefits associated with the adoption of BIM in the AEC industry. However, the benefits of BIM are discussed with limited reference to their relationship to the project stages and level of adoption among the AEC professionals

[567, 568]. In addition, there is a lack of understanding as to where, during the project lifecycle, BIM can provide benefits to the AEC, what some of the challenges are, and what the expected value is to the stakeholders [569]. Hence, there are no clear guidelines for the AEC team to follow to achieve the desired benefits of BIM. Moreover, this highlights the need for a clearer explanation of BIM benefits for AEC professionals to identify what they need to develop to achieve BIM benefits by optimizing their current efforts.

Thirdly, it has been observed that there is dispersion in investigating the BIM adoption drivers and factors – across several studies as a result of the specific theoretical lenses embraced by researchers. For instance, a study investigated the influence of only the isomorphic pressures (Coercive, mimetic, and normative pressures) in isolation from other factors (i.e., innovation characteristics and internal characteristics) due to employing the Institutional Theory (INT) [570] . Another study focused on exploring the impact of only two factors, namely, 'Perceived ease of use and Perceived usefulness" on BIM adoption as the researchers implemented the theory of Technology Acceptance Model as a theoretical lens to guide the investigation [571].

Finally, there are also critical shortcomings in existing BIM adoption studies which include the use of key terms and concepts like implementation, readiness, adoption, diffusion interchangeably. For example, the terms 'Adoption' and 'Implementation' were interchangeably used by some studies [572, 573, 574] "This blurs the distinction between interrelated concepts such as adoption, implementation, and diffusion [575].

These identified gaps from the literature necessitated the need to conduct an assessment of BIM adoption among the building industry firms in Nigeria. This study, therefore, was designed to fill the aforementioned gaps by investigating the level of BIM awareness and its adoption across the building stages, investigating BIM-compliant software applications as communication tools among building industry firms in Nigeria. In addition, the study assessed the knowledge of BIM benefits on adoption and optimization of its usage by building industry firms in Nigeria. Furthermore, the study evaluates the factors that influence BIM adoption.

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Chapter Three

Methodology

3.1 Research Design: Cross-Sectional Survey

The research design adopted for this thesis was a cross-sectional survey as it enabled the production of reliable and generalizable conclusions through quantitative analysis. A cross-sectional survey allowed the study to gather data at a single point in time, providing a snapshot of the current state of BIM adoption and implementation in the industry. This design enables the study to survey a broad range of participants, including architectural, engineering, quantity surveying, and building contracting firms, across various regions in Southwest Nigeria which provided a comprehensive overview of BIM usage. Also, it is well-suited for quantitative analysis as it allowed the study to quantify levels of BIM adoption, the frequency of use, and correlations between different variables . Some similar studies on BIM adoption also adopted a cross-sectional research design [1, 2, 3, 4, 5, 6].

3.1.1 Research Philosophy: Positivism

This study adopted the positivist research philosophical paradigm. The philosophy was best suited and helped in answering the research questions set in Chapter One of this thesis. The positivist approach was useful in assessing knowledge of BIM benefits on adoption and optimization of its usage by building industry firms in Nigeria. It was also used because it supported the investigation of different BIM software-compliant applications and the level of usage among building industry firms in Nigeria as it relates to collaboration among the ding professionals.

This is justifiable because positivism supports the use of quantitative methods, which are well-suited for measuring variables related to BIM adoption, such as levels of awareness, frequency of use, and impacts on project outcomes.

3.1.2 Research Approach: Deductive Approach

This study adopted a deductive approach. This is because the approach is often associated with quantitative research methods. Since the study involved collecting measurable data on BIM practices, this approach aligns well with statistical analysis, enhancing the robustness of the findings.

3.1.3 Research Strategy: Quantitative

This study adopted a Quantitative research strategy. This was because it involved the utilization and analysis of numerical data using specific statistical. Also, this strategy enabled the collection of data from a larger number of respondents, including architectural, engineering, quantity surveying, and building contracting firms which enhanced the representativeness of the study's findings. This is important for drawing generalizable conclusions about BIM adoption in the region.

3.2 Study Population

This study's population comprised the registered firms in the building industry in South-West Nigeria which is 892 (See Table 3.1). The sample frame consisted of architectural, building consulting and contracting, quantity surveying, and structural engineering films in the building industry in South-West Nigeria. South-West in Nigeria consists of the following states; Ekiti, Lagos, Ogun, Ondo, Osun, and Oyo. Generalizations from the study were made based on the study population.

3.3 Sample and Sampling Techniques

3.3.1 Sampling Techniques

This aspect explained the method and process used in selecting the analysis unit used in the study. In the study, multistage sampling approach were considered the most appropriate. This includes;

First stage: Purposive Sampling

In the first stage, purposive sampling was employed by selecting the state capitals in the southwestern states as they were adjudged to be the most urban with the highest number of built environment professionals and films, and also because of their relevance to the investigation under consideration. Therefore, a total of six (6) cities across six states in the geo-political zone (south-west) were considered for survey; Ado-Ekiti (Ekiti), Ikeja (Lagos), Abeokuta (Ogun), Akure (Ondo), Osogbo (Osun) and Ibadan (Oyo).

The study purposively chose architectural, building consulting and contracting, quantity surveying, and structural engineering films as they were firms with high use of BIM tools

Second Stage: Cluster Sampling

The second stage of the sampling involved sampling of the firms within the selected six cities for the study. A cluster sampling approach was adopted where clusters of films in the building industry were searched within each city. The clusters were based on the natural clusters identified within the six cities selected for this study.

Third Stage: Random Sampling

The third stage of the sampling involves a random selection of firms within each cluster identified. Firms within the clusters were randomly selected and principal partners were randomly selected to represent each film for questionnaire administration. One principal partner was selected in each of the randomly selected firms to represent their film.

3.3.2 Sample Size

The sample size is the portion of a population chosen to represent the population in research because time and expense may be constraints on the research, prohibiting it from examining the full population. As the sample is a subset of the population chosen to administer the research instruments, it is critical that it adequately represents the study population [7].

The sample size for this study was calculated to be 740 firms (Table 3.1). This value was derived by using Yamane's formula for each category of firms in each city; this was done to have an evenly distributed sample and a sample that properly represents the study population. Yamane's formula is represented as:

$n = \frac{N}{1+Ne^2}$ Where" n" is the sample size, "N" is the population, and "e" is the level of confidence (i.e. 95%).

The sample size was calculated from the sample frame drawn from the data provided by the Architects Registration Council of Nigeria (ARCON), the Council of Registered Builders of Nigeria (CORBON), the Nigerian Institute of Quantity Surveyor (NIQS), and the Council of Registered Engineers of Nigeria (COREN). The total sample frame for the study is 892 firms (i.e Ikeja = 493; Ibadan = 202; Abeokuta = 108, Addo-Ekiti = 30; Akure = 20; and Osogbo = 39) (Table 3.1)

Table 3.1: Sample Frame and Sample Size Distribution per City

	Ikeja (Lagos State)	Sample Size
Architectural Firm,	N=157 therefore, $n = \frac{N}{1+Ne^2} = \frac{157}{1+157(0.05)^2} = 113$	
Structural Engineering	N=118 therefore, $n = \frac{N}{1+Ne^2} = \frac{118}{1+118(0.05)^2} = 91$	
Quantity Surveying	N=92 therefore, $n = \frac{N}{1+Ne^2} = \frac{92}{1+126(0.05)^2} = 75$	
Building/Contracting	N=126 therefore, $n = \frac{N}{1+Ne^2} = \frac{126}{1+126(0.05)^2} = 96$	
		375 firms
	Ibadan (Oyo State)	
Architectural Firm,	N=57 therefore, $n = \frac{N}{1+Ne^2} = \frac{57}{1+57(0.05)^2} = 50$	
Structural Engineering	N=65 therefore, $n = \frac{N}{1+Ne^2} = \frac{65}{1+65(0.05)^2} = 56$	
Quantity Surveying	N=35 therefore, $n = \frac{N}{1+Ne^2} = \frac{35}{1+35(0.05)^2} = 32$	
Building/Contracting	N=45 therefore, $n = \frac{N}{1+Ne^2} = \frac{4}{1+45(0.05)^2} = 40$	

		178 firms
Abeokuta(Ogun State)		
Architectural Firm,	N=14 therefore, $n = \frac{N}{1+Ne^2} = \frac{14}{1+14(0.05)^2} = 13$	
Structural Engineering	N=15 therefore, $n = \frac{N}{1+Ne^2} = \frac{15}{1+15(0.05)^2} = 14$	
Quantity Surveying	N=32 therefore, $n = \frac{N}{1+Ne^2} = \frac{32}{1+32(0.05)^2} = 30$	
Building/Contracting	N=47 therefore, $n = \frac{N}{1+Ne^2} = \frac{47}{1+47(0.05)^2} = 42$	99 firms
Ado-Ekiti (Ekiti State)		
Architectural Firm,	N=7 therefore, $n = \frac{N}{1+Ne^2} = \frac{7}{1+7(0.05)^2} = 7$	
Structural Engineering	N=5 therefore, $n = \frac{N}{1+Ne^2} = \frac{5}{1+5(0.05)^2} = 5$	
Quantity Surveying	N=8 therefore, $n = \frac{N}{1+Ne^2} = \frac{8}{1+8(0.05)^2} = 8$	
Building/Contracting	N=10 therefore, $n = \frac{N}{1+Ne^2} = \frac{10}{1+10(0.05)^2} = 10$	
		30 firms
Akure (Ondo State)		
Architectural Firm,	N=4 therefore, $n = \frac{N}{1+Ne^2} = \frac{4}{1+4(0.05)^2} = 4$	
Structural Engineering	N=7 therefore, $n = \frac{N}{1+Ne^2} = \frac{7}{1+7(0.05)^2} = 7$	
Quantity Surveying	N=3 therefore, $n = \frac{N}{1+Ne^2} = \frac{3}{1+3(0.05)^2} = 3$	
Building/Contracting	N=6 therefore, $n = \frac{N}{1+Ne^2} = \frac{6}{1+6(0.05)^2} = 6$	
		20 firms
Osogbo (Osun State)		
Architectural Firm,	N=14 therefore, $n = \frac{N}{1+Ne^2} = \frac{13}{1+4(0.05)^2} = 13$	
Structural Engineering	N=8 therefore, $n = \frac{N}{1+Ne^2} = \frac{8}{1+7(0.05)^2} = 8$	
Quantity Surveying	N=12 therefore, $n = \frac{N}{1+Ne^2} = \frac{12}{1+3(0.05)^2} = 12$	
Building/Contracting	N=5 therefore, $n = \frac{N}{1+Ne^2} = \frac{5}{1+6(0.05)^2} = 5$	
		38 firms
N = 892 firms	:Sample Size =	740 firms

Sources: ARCON; CORBON; NIQS; COREN,(2020)

3.4 Description of the Research Instrument

3.4.1 Questionnaire Design

A closed-ended questionnaire was used as the research instrument for collecting primary data in this study. This questionnaire was divided into three (3) sections. Section A was designed to extract information about the demographic characteristics of the Nigerian building industry firms. Section B consists of questions on the level of awareness and usage of BIM-compliant software applications. Section C focused on the level of awareness and adoption of BIM uses across the building stages. Section D included questions on BIM benefits; while section E was designed to extract information on the barriers to and critical success factors of BIM adoption in the study area.

3.4.2 Identification, Specification and Operationalization of Variables

The variables in this study were the elements of interest to the researcher. They were quantifiable, and their values varied depending on the unit of analysis. Based on the research objectives, the questionnaire for the study was designed to include all of the factors of interest in the study (see Appendix I). Table 3.2 illustrates the identification, specification, and operationalization of variables for the study, which was utilized as a validity test for the study. The operationalization of the variables also allowed for the design of the questionnaire, which was utilized as the sole data collection method for the study (see Appendix I).

Table 3.2: Identification, Specification, and Operationalization of Variables of the Study Objective

S/N	Concepts And Questions	Variables and Measurements	Data Type
	Section A: Demographic Characteristics		

1	Types of Firm	Architectural (1), Structural Engineering (2), Building Consulting and Contracting (3), Quantity Surveying (4)	Nominal
2	Firms Location	Ikeja (Lagos) (1), Ibadan (Oyo) (2), Abeokuta (Ogun) (3), Osogbo (Osun) (4), Akure (Ondo) (5), Ado Ekiti (Ekiti) (6)	Nominal
3	Firm Size (by Staff)	< 10 staff (micro firm) (1), 11 – 50 staff (small firm) (2), 51 – 250 staff (medium size firm) (3), > 250 staff (large firm) (4) ,	Ordinal
4	Years in Operation (Age of the firm)	< 5 years (1), 6 - 10 years (2), 11 - 20 years (3), 21 - 30 years (4), > 30 years (5)	Ordinal
5	Area of Project Specialization	Mostly Commercial (1), Mostly Residential (2), Mostly Institutional (3), Mostly Industrial (4), All building types (5)	Nominal
6	Firms' Annual Turnover	< 1M (1), 1 – 10M (2), 11 – 50M (3), 51 – 100M (4), 101 – 250M (5), >250M (6)	Ordinal
7	Work Experience(Principal partner)	Years: < 5 years (1), 6-10 (2), 11 - 20 years (3), > 20 years (4)	Ordinal

Objective 1: identify common BIM software applications used in the Nigerian building industry.

1.	Heard of BIM	Yes (1), No (2), Not sure	Nominal
2	Software Applications (Awareness)	Multi-choice: Tekla Structures ( ) PowerCivil ( ) Archicad ( ) Digital Project ( ) ArchiFM ( ) Navisworks Manage () Green Building Studio ( ) Autodesk Quantity Takeoff ( ) Masterbill ( ) VICO Software ( ) Revit Architecture ( ) Bentley BIM Suite ( ) Skecthup ( ) QS CAD ( )	Nominal
3	Software Applications (Usage)	Multi-choice: Tekla Structures ( ) PowerCivil ( ) Archicad ( ) Digital Project ( ) ArchiFM ( ) Navisworks Manage ( ) Green Building Studio ( ) Autodesk Quantity Takeoff ( ) Masterbill ( ) VICO Software ( ) Revit Architecture ( ) Bentley BIM Suite ( ) Skecthup ( ) QS CAD ( )	Nominal

Objective 2: examine the awareness level of BIM uses across building stages in the Nigerian building industry

. **Design stage**	1.	Cost Estimation	1-5(Likert-scale): Not aware (1), Less aware (2), Not sure (3), Aware (4), Very aware (5)	Ordinal
	2.	Construction Planning	1-5(Likert-scale): Not aware (1), Less aware (2), Not sure (3), Aware (4), Very aware (5)	Ordinal
	3.	3D Coordination	1-5(Likert-scale): Not aware (1), Less aware (2), Not sure (3), Aware (4), Very aware (5)	Ordinal
	4.	Prefabrication	1-5(Likert-scale): Not aware (1), Less aware (2), Not sure (3), Aware (4), Very aware (5)	Ordinal
	5.	Visualization	1-5(Likert-scale): Not aware (1), Less aware (2), Not sure (3), Aware (4), Very aware (5)	Ordinal
	6.	Constructability Analysis	1-5(Likert-scale): Not aware (1), Less aware (2), Not sure (3), Aware (4), Very aware (5)	Ordinal
	7.	Sequencing	1-5(Likert-scale): Not aware (1), Less aware (2), Not sure (3), Aware (4), Very aware (5)	Ordinal
Construction stage	1.	Construction Monitoring	1-5(Likert-scale): Not aware (1), Less aware (2), Not sure (3),	Ordinal

			Aware (4), Very aware (5)	
	2.	Clash Detection	1-5(Likert-scale): Not aware (1), Less aware (2), Not sure (3), Aware (4), Very aware (5)	Ordinal
	3.	Maintenance Scheduling	1-5(Likert-scale): Not aware (1), Less aware (2), Not sure (3), Aware (4), Very aware (5)	Ordinal
	4	Fabrication	1-5(Likert-scale): Not aware (1), Less aware (2), Not sure (3), Aware (4), Very aware (5)	Ordinal
Maintenance/Operation Stage	1.	Asset Management	1-5(Likert-scale): Not aware (1), Less aware (2), Not sure (3), Aware (4), Very aware (5)	Ordinal
	2.	Building System Analysis	1-5(Likert-scale): Not aware (1), Less aware (2), Not sure (3), Aware (4), Very aware (5)	Ordinal
	3.	Record Modelling	1-5(Likert-scale): Not aware (1), Less aware (2), Not sure (3), Aware (4), Very aware (5)	Ordinal
Objective 3: evaluate the level of usage of BIM across the building stages in the Nigerian building industry				
1		Building stages	Multi-choice: Design ( ), Construction (), Maintenance ()	Nominal

2	Frequency of BIM Usage	1-5(Likert-scale): Never (1), Rare (2), Sometimes (3), Often (4) Always (5)	Ordinal
3	BIM Engagement for:		
	Construction Planning	( )	
	Visualization	( )	
	3D Coordination	( )	
	Cost Estimation	( )	
	Prefabrication	( )	
	Constructability Analysis	( )	Nominal
	Sequencing	( )	
	Construction Monitoring	( )	
	Clash Detection	( )	
	Maintenance Scheduling	( )	
	Fabrication	( )	
	Asset Management	( )	
	Building System Analysis	( )	
	Record Modelling	( )	

Objective 4: analyze the significant BIM benefits in the Nigerian building industry

1.	Improve project design	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
2.	better clash detection	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very	Ordinal

		important(5)	
3.	better coordination	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
4.	Reduce Rework in Construction	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
5.	better synchronization	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
6.	better projects sequencing	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
7.	give room for more off-site materials/components prefabrication	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
8.	enable visualization of the built environment	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
9.	improves health and	1-5(Likert-scale): Not	Ordinal

	safety	important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	
10.	Allow for flexibility and sustainable design	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
11.	facilitate equipment and asset maintenance and management	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
12.	Provides a digital model that can be utilized throughout the building life cycle.	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
13.	more accurate and speedy estimation of project cost and time	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
14.	improvement in energy efficiency	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
15.	improve resources planning and sequencing	1-5(Likert-scale): Not important (1), Somewhat important	Ordinal

		(2), Neutral (3), Important (4) Very important(5)	
16.	effective management of project resources procurement and storage	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
17.	allows for effective and efficient utilization of site	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
18.	Improves efficiency and productivity	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
19.	Improves decision making at the operation and maintenance of a facility.	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
20.	Access to information is fast and reliable	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
21.	Provision of accurate and updated information	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very	Ordinal

		important(5)	
22.	Improving team building skills	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
23.	monitor and track progress during construction	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
24.	Improve services delivery	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
25.	Project cost reduction	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
26.	Reduced Construction Time	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
27.	Improve project Quality	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
28.	Improve project	1-5(Likert-scale): Not	Ordinal

	documentation	important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	
29.	improve multi-party communication and collaboration	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	Ordinal
30.	Minimize Errors and mistakes	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	
31.	Constructability improvement	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	
32.	Minimizes disputes and conflicts	1-5(Likert-scale): Not important (1), Somewhat important (2), Neutral (3), Important (4) Very important(5)	
Objective 5: identify factors that influence the adoption of BIM in the Nigerian building industry			
Limiting factors/barriers			
1	Unwillingness to use BIM	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
	Lack of Experience and	1-5(Likert-scale):	Ordinal

	skills	Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	
2	Negative Perception of Ease of Use	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
3	Personal Incompetency	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
4	Abasenceork motivation	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
5	Lack Interest	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
6	Ignorant of BIM usefulness	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
7	Availability of technical infrastructure	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
8	Financial resources	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4),	Ordinal

		Strongly Agree (5)	
9	Unvailability of BIM users	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
10	Perceived risks	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
11	Organizational readiness	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
12	Organization's culture	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
13	Organization's capacity	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
14	Organization's policies	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
15	Lack of Manager's support	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal

16	Lack of Capacity to use information technology	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
17	Ignorance of benefits of BIM for organization	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
18	Technology Quality	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
19	Speed of BIM tools	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
20	BIM complexity	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
21	Trialability	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
22	Speed of BIM tools	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
23	IT support	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure	Ordinal

		(3), Agree (4), Strongly Agree (5)	
24	Result demonstrability	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
25	Accessibility	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
26	Functionality	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
27	Feasibility using BIM	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
28	Procurement methods	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
29	Stakeholders interaction	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
30	Project scale	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal

31	Stakeholders' awareness	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
32	Project requirements	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
33	Project complexity	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
34	BIM standards	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
35	BIM instructions	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
36	BIM providers	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
37	Competition levels	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
38	Laws and policies	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure	Ordinal

		(3), Agree (4), Strongly Agree (5)	
39	Lack of Government support	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
Critical Success Factors (CSFs) for BIM Adoption			
40	Incorporation of BIM into academic curriculum	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
41	Improve BIM awareness and understanding	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
42	Outsourcing BIM experts	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
43	Provision of training by employers	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
44	Government Legislation supporting the use of BIM	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
45	Developing BIM guidelines	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal

46	Reduction in cost of implementing BIM	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
47	Setting up BIM council	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
48	Compulsory use of BIM for all procurement and contract	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal
49	Provision of appropriate technology and infrastructure	1-5(Likert-scale): Strongly Disagree(1), Disagree (2), Not Sure (3), Agree (4), Strongly Agree (5)	Ordinal

Source: Author's Field Survey, 2024

3.5 Validity Tests

Validity deals with how meaningful the components of the research are. This implies it shows how well the research instrument measures the right thing it was designed to measure [8]. Therefore, this study adopted the construct validity approach using the content test method. This was conducted by operationalising the variables for the studies. Several questions were asked and they were subjected to the research supervisor's and expert review. The operationalization of variables is presented in Table 3.2. This validity ensured that questions in each construct successfully described and measured the construct in the questionnaire and thus, ensured that the questions asked covered the objectives of the study.

This is justifiable as indicated that social science researchers should consider these four important validity tests in their research [9]. These are:

1) Statistical conclusion validity:

This tends to look at if a relationship exists between two variables. It involves inferences made if it is rational to presume a co-variation between the two variables if an alpha level and variances obtained are given. This method can be disadvantageous if the statistical power of the researcher is weak, assumptions are debased, measures and treatment of measures reliability are low, and there is a presence of random error in test administration and random heterogeneity in the respondents [10].

2) Internal validity: This deals with the validity of the research. Internal validity looks at the relationships that exist between the variables. If they are causal or there are other factors responsible for the relationships in that study. It looks at, if the instrument truly tests the situation being tested or the result gotten from the test is because of some internal influencing factors. This validity is limited by threats such as maturation, history, understanding of instrument, respondent's selection, diffusion of treatments, compensation and many internal influences [11].

3) Construct validity: Looks at how well the concept to be tested is transferred into a working reality in the data collection instrument. This implies how well the variables in the research are operationalised. Construct validity is carried out using face, content, concurrent and predictive, and, convergent and discriminative validity methods [21].

3.6 Reliability Test- Pilot Study

The reliability of a study is concerned with how the measurement produced from a study is consistently repeated by someone else measuring the same object at different times and under different conditions. As a result, the reliability test demonstrates how consistent or stable a measure is under a variety of conditions and circumstances where the same or comparable results are expected. Random mistakes are the main focus of reliability. It is commonly calculated using association measures known as correlation coefficients or coefficients of reliability; this is the correlation between two or more measurements that are supposed to measure the same concept. A measure's reliability is concerned with equivalence, stability across time, and internal consistency [12, 13, 14].

However, for this study, the internal consistency approach was used to establish the reliability of the study instrument. This was done to ensure adequate questionnaire design and pre-testing via a pilot survey conducted on a sample of the same type. For the pilot study, a questionnaire administration strategy was used. 100 stakeholders in the building industry were given the study's questionnaire, and they were asked to complete it on behalf of their companies. The majority of the questionnaire's constructs were scored on a 5-point Likert scale (see Appendix 1). The study was completed in four weeks, and the replies were gathered through mail. The purpose of the pilot test was to enable the researcher to determine whether the instrument had any unclear or confusing questions and whether the questions measured the variables the researcher wished to study. The researcher was able to modify certain items in the questionnaire, particularly those about the knowledge and adoption of BIM, with the assistance of the respondents' responses.

The Cronbach alpha reliability test was performed on the variables of each research objective. The results, as shown in Table 3.3, reveal that all constructs have values more than the recommended minimum of 0.7 alpha, implying that the instrument was reliable because all scales of measurement consistently measured the constructs as intended.

Table 3.3: Reliability by Objectives (Ordinal Variables)

Objectives	Cronbach's Alpha	No of items
Objective 1	0.920	14
Objective 2	0.862	14
Objective 3	0.804	12
Objective 4	0.815	32
Objective 5	0.864	49

Source: Source: Author's Field Survey, (2024)

3.7 Method of Data Collection

Due to the nature of the research strategy (quantitative) of the study, primary data were collected through a well-structured questionnaire, which was administered by the researcher and trained field assistants to the sampled Architectural, structural engineering, quantity surveying, and building-contracting firms in the study area. The research was carried out simultaneously in Lagos, Ibadan, Abeokuta, Akure, Ado-Ekiti, and Osogbo with the help of trained research assistants. The administration and retrieval of copies of the questionnaire took place between June 2023 And November 2023. In each of the selected firms, a principal partner was selected to represent the firms in questionnaire filling. A total of 740 copies of the questionnaire were administered however, 656 copies representing 88.6% of the distributed questionnaires were retrieved and considered for analysis (see Table 3.4).

Table 3.4 Data Collection-Questionnaire Administration

S/N	Questionnaire	Number	Percentage
1	Distributed	740	100
2	Retrieved	656	88.6
3	Not Returned	78	10.6

Source: Author's Field Survey, 2024

3.8 Data Characteristics, Sources, and Analysis by Objectives

Objective 1

To examine common BIM software applications used in the building industry in southwest Nigeria

Data Characteristics: The data for objective 1 are nominal and quantitative in nature. The variables are as stated in Table 3.2

Data Source: The data for this objective were directly sourced from building industry stakeholders (principal partners) in the sampled firms. This was sourced from a questionnaire administration (see Appendix 1).

Data Analysis: The data for this objective were analyzed using descriptive statistics like frequencies, means, percentages, cross-tabulation; and results were presented in tables and charts.

Objective 2:

To assess the awareness level of BIM use across building stages in the building industry in southwest Nigeria.

Data Characteristics: The data for objective 2 are ordinal and quantitative in nature. The variables are as stated in Table 3.2.

Data Source: The data for this objective were directly sourced from building industry stakeholders (principal partners) in the sampled firms. This was sourced from a questionnaire administration. (see Appendix 1)

Data Analysis: The data for this objective were analyzed using frequency distribution, percentages, means, and standard deviation, and results were presented in tables and charts.

Objective 3:

To identify the level of usage of BIM across the building stages in the building industry in southwest Nigeria.

Data Characteristics: The data for objective 3 are nominal and ordinal, as well as quantitative in nature. The variables are as stated in Table 3.2.

Data Source: The data for this objective were directly sourced from building industry stakeholders (principal partners) in the sampled firms. This was sourced from a questionnaire administration. (see Appendix 1)

Data Analysis: The data for this objective were analyzed using frequency distribution, percentages, means, standard deviation, and Analysis of Variance (ANOVA); and results were presented in tables and charts.

Objective 4:

To evaluate the factors that influence the adoption of BIM in the building industry in southwest Nigeria

Data Characteristics: the data for objective 5 are ordinal and quantitative in nature. The variables are as stated in Table 3.2.

Data Source: The data for this objective were directly sourced from building industry stakeholders (principal partners) in the sampled firms. This was sourced from a questionnaire administration. (see Appendix 1)

Data Analysis: The data for this objective were analyzed using frequency distribution, percentages, means, standard deviation, factor analysis, and Kruskal-Wallis Test; and results were presented in tables and charts.

Objective 5:

To analyze the significant BIM benefits in the Nigerian building industry

Data Characteristics: The data for objective 4 are ordinal and quantitative in nature. The variables are as stated in Table 3.2.

Data Source: The data for this objective were directly sourced from building industry stakeholders (principal partners) in the sampled firms. This was sourced from a questionnaire administration. (see Appendix 1)

Data Analysis: The data for this objective were analyzed using frequency distribution, percentages, relative importance index (RII), and Kruskal-Wallis Test; and results were presented in tables.

Table 3.5: Summary of Research Design

Objectives	Types of Data	Nature of Data	Types of Analyses
Objective 1 *To examine the common BIM software applications used in the Nigerian building industry*	Quantitative	Nominal	Descriptive statistics like frequencies, means, and percentages; and results were presented in tables and charts.
Objective 2 *To assess the awareness level of BIM uses across building stages in the*	Quantitative	Ordinal	Frequency distribution, percentages, means, standard deviation, and correlation analysis; and results were presented in tables and charts.

Nigerian building			
Objective 3 *To identify the level of usage of BIM across the building stages in the Nigerian building industry*	Quantitative	Nominal, Ordinal	Frequency distribution, percentages, means, standard deviation, and Analysis of Variance (ANOVA); and results were presented in tables and charts.
Objective 4 *To analyze the significant BIM benefits in the Nigerian building industry*	Quantitative	Ordinal	Frequency distribution, percentages, relative importance index (RII), and Kruskal-Wallis Test; and results were presented in tables.
Objective 5 *To identify factors that influence the adoption of BIM in the Nigerian building industry*	Quantitative	Ordinal	Frequency distribution, percentages, means, standard deviation, factor analysis, and Kruskal-Wallis Test; and results were presented in tables and charts

Source: Author's Field Survey, 2024

3.9 Ethical Approval

Ethical consideration is how to authenticate the collection of data to prevent falsification and fabrication, minimize error, and promote knowledge and truth as well as to guard against the infringement of human rights in the course of the research. As this research involved interaction with the human population both at home and workplace, it is important to establish trust with participants, where rights were respected. Therefore, full consent was obtained from participants of the research, using content forms, and the privacy of the participants would not be violated in the administration of questionnaires. In reporting the finding, the highest level of confidentiality and anonymity was maintained as no information provided by any participant would be linked to him/her. The research process was clearly stated to respondents, providing the aim and objectives, so that responses obtained would be as true as possible without external influences. The views of the participants were respected and protected, and the data was carefully stored and protected to avoid access by unauthorized persons.

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Chapter Four

Results and Discussion of Findings

4.1 Demographic Data Analysis

This chapter presents and discusses the analysis of the data gathered for the study. Additionally, it demonstrates how the findings addressed the prior questions that framed the research. The results obtained and their comparison with findings from the literature are further discussed in the chapter. The results presented here cover respondents' demographic characteristics; different BIM software applications and their relative usage in the building industry; awareness level of BIM uses across building stages; level of usage of BIM across the building stages; factors that influence the adoption of BIM in the Nigerian building industry; and significant BIM benefits in the Nigerian building industry.

4.1.1 Demographic Characteristics of the Firms

The respondents' firms' characteristics were grouped based on their types, locations, years in operation (age of the firm), area of specialization, annual turnover, and work experience, as shown in Table 4.1. The results in Table 4.1 indicated that 26.4% of the sampled firms were Architectural, 24.7% were structural engineering, 27.1% were building contracting and 21.8% were quantity surveying firms. It was revealed that 51.1% of the sample firms were located in Ikeja (Lagos state), 24.2% were located in Ibadan (Oyo state), 13.6% were located in Abeokuta (Ogun state), 5.2% were located in Osogbo (Osun state), 4.0% were located in Akure (Ondo state), and 2.0 % were located in Ado-Ekiti(Ekiti state) as displayed in Table 4.1. It was also discovered that 47.9% of the sampled firms were micro (< 10 staff), 25.0% were small-size firms (11 – 50 staff), 18.8% were medium-size (51 – 250 staff), and 18.8% were large-size (firm > 250 staff).

The respondents' experience was impressive: 43.8% had worked in the building industry for more than 20 years, 18.8% had experience between 11 and 20 years, and 37.5% had experience of at least 10 years or less. Moreover,

most respondents’ project specializations are residential and all building types, accounting for 21.7 and 67.5% of responses, respectively. The information above inferred that the respondents are highly experienced and have played significant roles in their firms. Their opinion on the survey's relevance is significant because of these qualities, making it confidently reliable.

Furthermore, Table 4.1 shows that 9.7% of the sampled firms had an income annual turnover of less than 1M, 11.3% had an income annual turnover of 1-10M, 12.5% had an income annual turnover of 11-50M, 14.3% had an income annual turnover of 51-100M, 19.7% had an income annual turnover of 101 – 250M, and 32.5% had an income annual turnover more than 250M.

Table 4.1 Demographic Characteristics of the Firms

Variable		Frequency	Percentage (%)
Types of Firm	Architectural	173	26.4
	Structural Engineering	162	24.7
	Building Consulting and Contracting	178	27.1
	Quantity Surveying	143	21.8
Firms Location	Ikeja (Lagos)	335	51.1
	Ibadan (Oyo)	159	24.2
	Abeokuta (Ogun)	89	13.6
	Osogbo (Osun)	34	5.2
	Akure (Ondo)	26	4.0
	Ado Ekiti (Ekiti)	13	2.0
Firm Size (by Staff)	< 10 staff (micro firm)	325	47.9
	11 – 50 staff (small firm)	164	25.0
	51 – 250 staff (medium size firm)	123	18.8
	> 250 staff (large firm)	54	8.3
Years in Operation (Age of the firm)	< 5 years	54	8.2
	6 - 10 years	83	12.7
	11 - 20 years	218	33.2
	21 - 30 years	178	27.1
	> 30 years	123	18.8
Area of Project Specialization	Mostly Commercial	30	4.6
	Mostly Residential	142	21.7
	Mostly Institutional	27	4.1
	Mostly Industrial	14	2.1
	All building types	442	67.5
Firms' Annual	< 1M	64	9.7

Turnover	1 – 10M	74	11.3
	11 – 50M	82	12.5
	51 – 100M	94	14.3
	101 – 250M	129	19.7
	>250M	213	32.5
Work Experience	< 5 years	54	8.2
	6 - 10 years	192	29.3
	11 - 20 years	123	18.8
	> 20 years	287	43.8

Source: Author;s Computation, (2024)

4.2 Presentation of Data

Objective1: examine the common BIM software applications used by building firms in southwest Nigeria.

4.2.1 Common BIM Software Applications and their Relative Usage in the Nigeria Building Industry

The use and awareness of BIM-compliant software in the Nigerian building industry is depicted in Figure 1. The literature identified fourteen (14) software products that comply with BIM. 42.1% of respondents were aware of Tekla Structures while 17.1% used it; 86% were aware of Archicad while 36% used it; 47.7% were aware of ArchiFM while 37.2% used it; 8.2% were aware of Green Building Studio while 2% used it; 69.4% were aware of Masterbill while 21% used it; 75% were aware of Revit Architecture while 64.8% used it; 85.1% were aware of Sketch-Up while 59% used it; 74.7 were aware of Power Civil while 19.4% used; 10.1% were aware of Digital Project while 1.1% used it; 92.1 were aware of Navistwork Manager while 55.9% used; 99.7% were aware of AutoCAD while 95% used; 38% were aware of VICO Software while 9% used; 92.1% were aware of Bentley BIM Suite and 89.9% were aware of QS CAD while 25% used it.

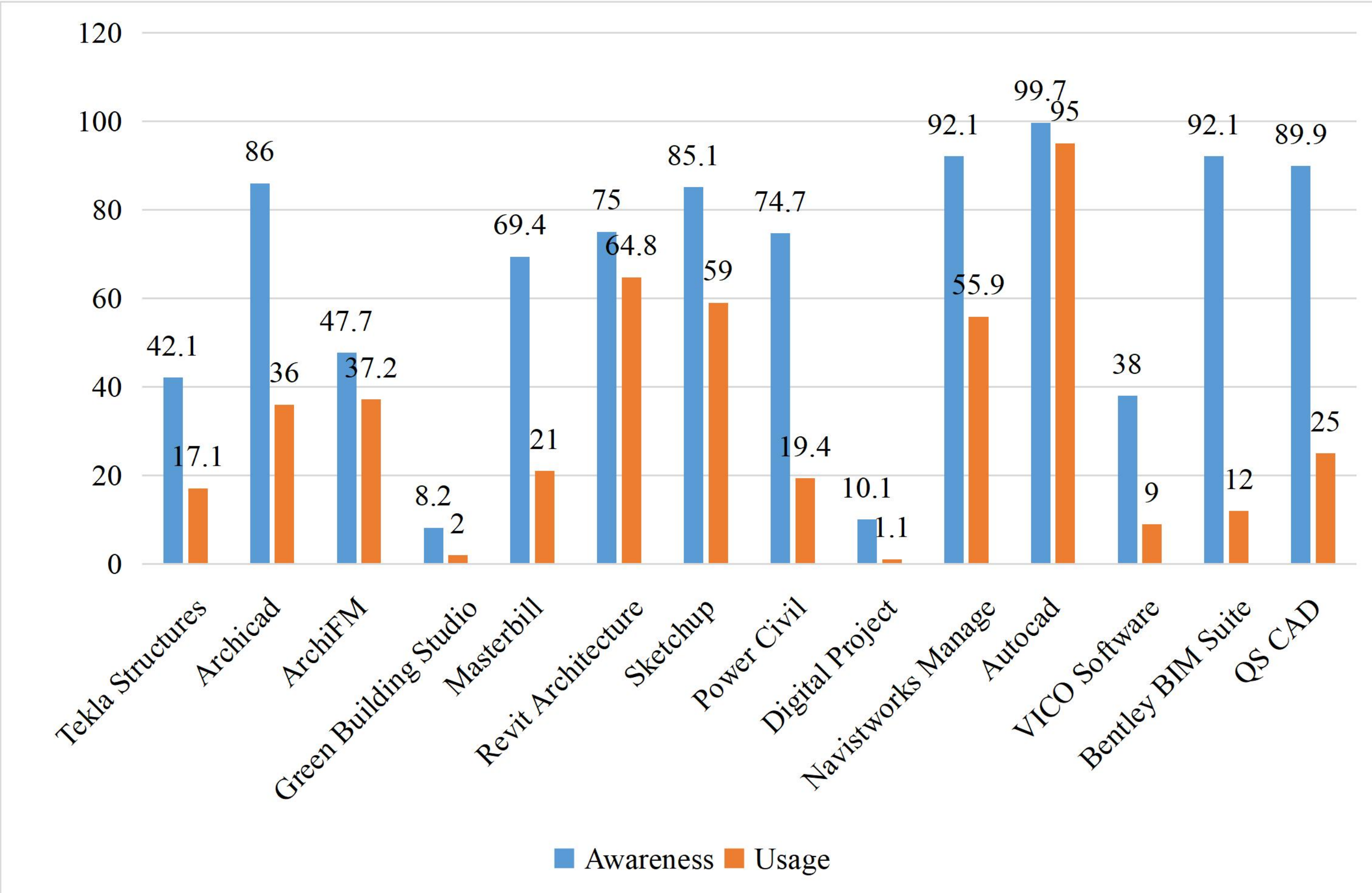

Figure 4.1: BIM Compliant Software Awareness and Usage

Source: Author's Computation, (2024)

Based on average, it can be inferred that most of the respondents' firms were aware of software packages that comply with BIM, but the level of usage was not commensurate with the level of awareness. This could be a result of the barriers mitigating against BIM adoption as stated by [1]. A study also asserted that the majority of experts in the Nigerian building industry have also been unable to use BIM-compliant software packages due to technical issues with the packages and insufficient training provided to staff members [2]. The study revealed that AutoCAD, Revit Architecture, and Sketch-Up were the most often utilized software products. According to earlier studies, these software programs are CAD tools that enable architects to create architectural plans, arrange layouts, and create conceptual elements [3, 4]. They also enable architects to present finished design drawings to clients electronically [5].

Furthermore, in order to know which BIM applications are peculiar to the building industry firm types, a Crross tab descriptive analysis was conducted and the result is presented in Table 4.2. The study revealed that Autocad, Archicad, Green Building Studio, Revit Architecture, Sketchup, and Digital Project are BIM applications mostly used by the architectural firms; Tekla Structures, Revit Architecture, Power Civil, and Autocad are mostly used by the structural firms; ArchiFM, Revit Architecture, and Autocad are commonly found with building contracting firms while ArchiFM, MasterBill, Revit Architecture, Autocad, and QS CAD are BIM tools that are peculiar to quantity surveying firms. These are the BIM tools whose engagement by the building industry firms are above 50%. The study also found out as shown in Table 4.2 that Revit architecture and Autocad are the two BIM applications that are widely used across the building industry firms. This implies that the building industry firms used this two applications mostly and evenly for collaboration and communication. They used them to share and exchange files.

Table 4.2: Crosstabulation of BIM Compliant Software with Firm Types

S/N	BIM Applications/Firm	Architectural F/%	Structural Engineering F/%	Building Contracting F/%	Quantity Surveying F/%
i.	Tekla Structures	10/5.8	*158/97.5	4/2.2	0/0
ii.	Archicad	*107/62.0	26/16.0	44/24.7	6/4.2
iii.	ArchiFM	81/47.0	44/27.2	*117/65.7	*104/72.7
iv.	Green Building Studio	*90/52.0	14/8.90	19/10.7	22/15.4

v.	MasterBill	68/39.3	44/27.1	63/35.4	*141/98.6
vi.	Revit Architecture	*172/99.4	*83/51.2	*104/58.4	*75/52.4
vii.	Sketchup	*151/87.3	66/40.7	*110/61.8	21/14.7
viii.	Power Civil	0/.00	*117/72.1	0/.00	36/25.2
ix.	Digital Project	*99/57.2	30/18.5	0/.00	0/.00
x.	Navisworks Manager	55/31.8	25/15.4	0/.00	0/.00
xi.	Autocad	*171/98.8	*114/70.4	*122/68.5	*94/65.7
xii.	VICO Software	26/15.0	22/13.6	0/.00	0/.00
xiii.	Bentley BIM Suite	6/3.5	20/12.3	3/1.7	0/.00
xiv.	QS CAD	4/2.3	0/.00	2/1.1	*142/99.3

Source: Author; Computation, (2024)

Objective 2: Assess the awareness level of BIM use across the building stages in the building industry in southwest Nigeria.

4.2.2 Awareness Level of BIM Use across the Building Stages in the Building Industry in Southwest Nigeria

This section presents result of the study on the level of awareness and extent of knowledge of respondents about building information modelling BIM and its uses in the Nigerian Building Industry. Respondents were initially asked of their awareness of BIM (see section D – No 10 of questionnaire in the Appendix 1) and the result is presented in Figure 4.1. In addition, this section presents the respondents' level of awareness of BIM in each location of the study.

4.2.2.1. Awareness of BIM among the Building Firms in the Southwest Nigeria

Figure 4.2 precisely reveals that 21% of the respondents' had not heard and were not aware about BIM, 7% of the sample were not sure if they have heard about BIM or not, while 72.0% of the respondents had heard and were aware of BIM. This result suggests that large proportions of the firms from where the respondents were drawn has heard about or are aware of the existence of building information modelling in the building industry. This implies that the level of awareness of BIM is high among firms in the building industry in southwest Nigeria.

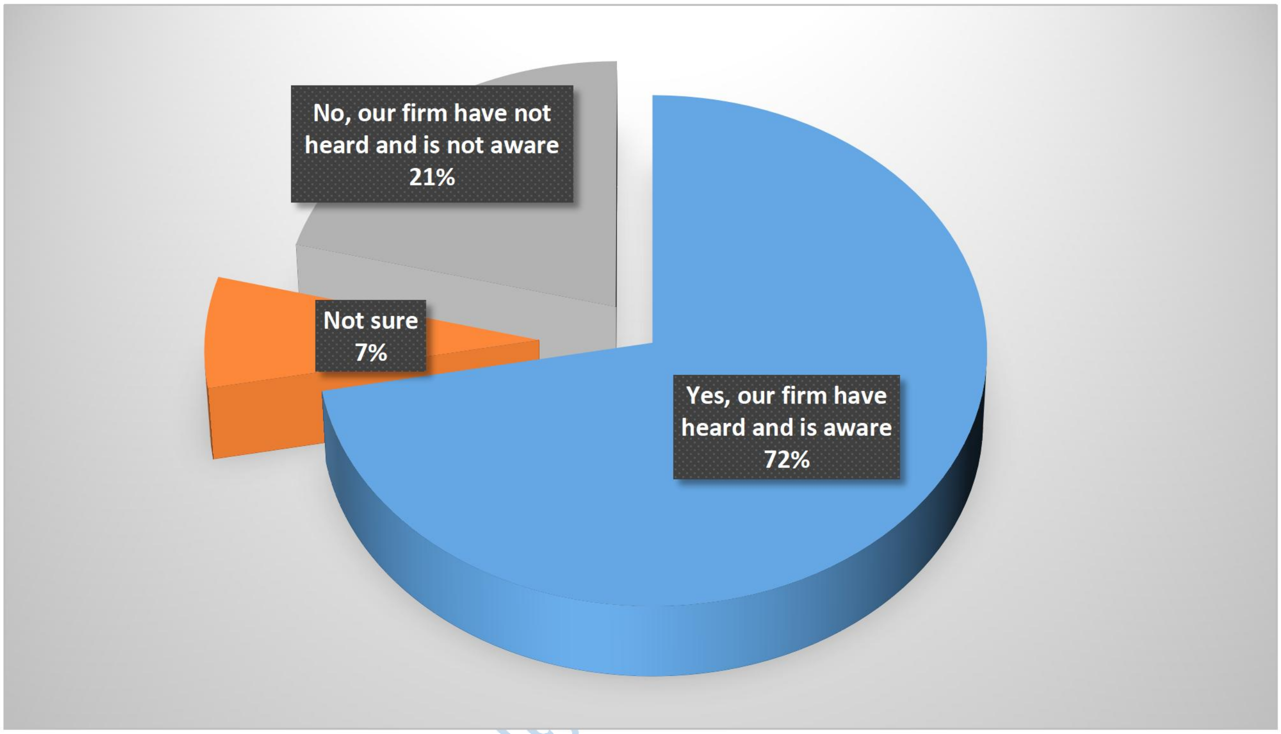

Figure 4.2: BIM Awareness

Although findings from some study indicated that BIM awareness in the Nigerian construction industry was low [6, 7, 8, 9] . This also aligns with a similar study in Croatia [10]. The specific finding of the current study seems to be contrary to findings from these literatures aforementioned as presented in Figure 4.2. The result of this study as displayed in Figure 4.2 shows that BIM awareness is high among stakeholders in the Nigerian building industry. The difference in the years between these two studies and the geographic coverage of the current study might be the reason for the variation in the results.

In addition, the result from this study as shown in Figure 4.2 aligns with findings from a study carried out in the northern part of Nigeria, where awareness of building information modeling among architecture, engineering and construction (AEC) was observed to be good [11]. Furthermore, results from this study as presented in Figure 4.2 supports the findings from a study which was carried out in Port-Harcourt, Rivers State, Nigeria which indicated that there is an increasing level of awareness among building consulting firms in the Nigerian building industry. This shows that the level of awareness in the Nigerian building industry about building information has significantly increased after 10 years of the study conducted by a researcher on BIM awareness [12].

Certainly, this trend could imply that there is a possibility of BIM adoption in the Nigerian building industry. Therefore, the observed level of awareness of BIM is expected to have a positive impact on the adoption as postulated by Rogers theory who stated that the process of any innovation diffusion begins with the knowledge stage which involves awareness knowledge, application knowledge, and principle knowledge. This suggests that around 72% of the firms in the Nigerian building industry who indicated that they had heard and were aware about BIM (use) in this survey are most likely to adopt them in the delivery of building projects.

Moreover, crosstab analysis and chi-square test were conducted on the firm types and overall BIM awareness to explore whether there is a statistically significant relationship between the firm types and overall BIM awareness. From the Cross tab analysis as displayed in Table 4.3a, it found that the architectural firm had the highest frequency count (162) on the response "**Yes, our firm have heard and is aware**" while the Quantity surveying firm had the least frequency (120). From Cross Tab analysis, it is impossible to tell whether there is a statistically significant relationship between these groups on Overall BIM Awareness, therefore, a Chi-Square test was conducted to ascertain this. The results of Chi-Square showed that no significant relationship exists between the firm types and the Overall BIM Awareness; (x^2 (656, N=656) = 3.17, P > .05).

Table 4.3a: Cross-Tabulation (Firm Types and BIM awareness)

Firms' Types	Yes, our firm have heard and is aware	Not sure	No, our firm have not heard and is not aware	Total
Architectural	162 (93.6)	11(6.4)	0(0.00)	173(100.0)
Engineering	149(92.0)	10(6.2)	3(1.8)	162(100.0)
Building Contracting	151(84.8)	20(11.2)	7(4,0)	178(100.0)
Quantity Surveying	120(83.9)	14(9.8)	9(6.3)	143(100.0)

Note: values in the bracket are percentages

Source: Author's Computation, (2024)

Table 4.3b. Chi-Square Tests of Association

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	3.171[a]	2	0.60
Likelihood Ratio	3.217	2	0.85
Linear-by-Linear Association	1.106	1	0.12
N of Valid Cases	654		

Source: Author's Computation, (2024)

Furthermore, to understand the respondents' level of awareness in each of the six capital cities in Southwest Nigeria from where the study drew the sample, a Crosstab descriptive analysis was also conducted and the result is presented in Table 4.3c.

Table 4.3c: Cross-Tabulation of Respondents Level of BIM Awareness per Location

Firms' Location	Yes, our firm have heard and is aware	Not sure	No, our firm have not heard and is not aware	Total

Ikeja (Lagos)	325(97.0)	7(2.0)	3(1.0)	335(100.0)
Ibadan (Oyo)	133(83.4)	8(5.4)	18(11.2)	159(100.0)
Abeokuta (Ogun)	63(70.2)	5(6.0)	21(23.8)	89(100.0)
Osogbo (Osun)	21(60.4)	3(10.5)	10(29.1)	34(100.0)
Akure (Ondo)	16(60.1)	2(8.9)	8(31.0)	26(100.0)
Ado Ekiti (Ekiti)	8(59.8)	1(9.4)	4(30.8)	13(100.0)
	566(72.0)	26(6.9)	64(21.1)	656(100.0)

Note: values in the bracket are percentages

Source: Author's Computation, (2024)

Results presented in Table 4.3c reveal that 97.0% of respondents in Lagos indicated that their firms were aware of BIM, 83.4% were aware in Ibadan, 70.2% were aware in Abeokuta, 60.4% in Osogbo, 70.2% were aware in Abeokuta, (60.1)% in Akure and 59.8% in Ado Ekiti. This implies that even though the number of respondents in each of the cities was not equal in number, the result as presented in Table 4.3 suggests that the awareness level of building information modeling is high among the building firms in the study area and this is topped by firms in Lagos followed by Ibadan.

4.2.2.2 Extent of Awareness of BIM (Uses) across the Building Stages

In order to understand the extent of knowledge of the respondents about BIM and its uses, they (the respondents) were asked questions on their level of awareness about the use of BIM in building design and construction activities. Table 4.4 shows fourteen (14) BIM uses as identified from the literature. These BIM uses are then categorized into three stages of building construction (Design Stage, Construction / Building Stage, and Operation / Facility Management Stage). Question asked for this section was based on a 5- point Likert Scale where 1 represents **Not Aware**; 2 represents **Less Aware**; 3 represents **Not Sure**; 4

represents **Aware**, and 5 represents **Very Aware**. This measured respondents' familiarity and knowledge base about BIM (uses) across the building stages.

It was found from the result presented in Table 4.4 that although 72% of respondents indicated awareness about BIM as aforementioned it is however evident that only about 70.8% of respondents firm are either aware or very aware that BIM can be used for construction planning, 13.7% were not sure. In comparison, 13.7% were either not or less aware that it can be used for construction planning. Also, it was discovered that 69.2% of respondents were either aware or very aware that BIM can be used for visualization, and 15.0% were not sure. In comparison, 15.9% were either not or less aware that it can be used for visualization. This implies that there is a progressive increase in BIM knowledge among stakeholder firms in the Nigerian Building Industry.

Under the Design Stage as shown in Table 4.2, seven BIM uses were identified with mean scores ranging between 2.84 and 3.95. These BIM uses at the design stage ranged from construction planning to sequencing which is the least ranged. To get the BIM use respondents are very much aware of at the design stage, a mean score threshold of 3.00 was set. As a result, only six (6) BIM uses were above 3.00 and considered significant. These BIM uses are: Construction Planning (Mean = 3.95; SD = 1.230), Visualization (Mean = 3.84; SD = 1.255), Coordination (Mean = 3.72; SD = 1.291), Cost estimation (Mean = 3.71; SD = 1.226), Prefabrication (Mean = 3.70; SD = 1.247), and Constructability Analysis (Mean = 3.23; SD = 1.435).

Under the Construction / Building Stage, four (4) BIM uses were identified with a mean score ranging between 2.80 and 3.09. BIM uses at the construction/building stage ranged from construction monitoring to prefabrication which is the least ranged. To get the BIM use respondents are very much aware of at the construction/building stage, a mean score threshold of 3.00 was also set. As a result, only two (2) BIM uses were above 3.00 and considered significant. These BIM uses were Construction monitoring (Mean = 3.09; SD = 1.417), and Clash Detection (Mean = 3.02; SD = 1.398).

Under the Operation/ Facility Management Stage, three (3) BIM uses were identified with a mean score ranging between 2.49 and 2.92. BIM uses at the maintenance/operation stage ranged from Asset Management to Record Modelling which is the least ranged. To get the BIM use at the operation/ facility management stage, a mean score threshold of 3.00 was also set and no BIM use is above 3.00. This indicates that the majority of the respondents are not very aware of the use of BIM at the operation/ facility management stage.

Table 4.4: Awareness of BIM Uses Across Building Stages

S/N	Variables	VA (%)	A (%)	NS (%)	LA (%)	NA (%)	Mean	SD	Rank
				Design Stage					
1	Construction	264	248	56	24	64	3.95	1.230	1

	Planning	(40.2)	(30.6)	(13.7)	(3.7)	(9.8)			
2	Visualization	240 (36.6)	240 (32.6)	72 (15.0)	40 (6.1)	64 (9.8)	3.84	1.255	2
3	3D Coordination	224 (34.1)	216 (32.9)	88 (13.4)	64 (9.8)	64 (9.8)	3.72	1.291	3
4	Cost Estimation	200 (30.5)	232 (35.4)	112 (17.1)	56 (8.5)	56 (8.5)	3.71	1.226	4
5	Prefabrication	192 (29.3)	264 (40.2)	64 (9.8)	80 (12.2)	56 (8.5)	3.70	1.247	5
6	Constructability Analysis	152 (23.2)	192 (29.3)	88 (13.4)	104 (15.9)	120 (18.3)	3.23	1.435	6
7	Sequencing	88 (13.4)	160 (24.4)	120 (18.3)	136 (20.7)	152 (23.2)	2.84	1.376	7
				Construction Stage					
1	Construction Monitoring	128 (19.5)	176 (26.8)	104 (15.9)	120 (18.3)	128 (19.5)	3.09	1.417	1
2	Clash Detection	120 (18.3)	160 (24.4)	120 (18.3)	128 (19.5)	128 (19.5)	3.02	1.398	2
3	Maintenance Scheduling	88 (13.4)	144 (22.0)	136 (20.7)	136 (20.7)	152 (23.2)	2.82	1.364	3
4	Fabrication	88 (13.4)	136 (20.7)	144 (22.0)	136 (20.7)	152 (23.2)	2.80	1.357	4
				Operation/Facility Management Stage					
1	Asset Management	80 (12.2)	152 (23.2)	120 (18.3)	160 (24.4)	144 (22.0)	2.79	1.342	1
2	Building System Analysis	64 (9.8)	152 (23.2)	128 (19.5)	144 (22.0)	168 (25.6)	2.70	1.333	2
3	Record Modelling	64 (9.8)	144 (22.0)	136 (20.7)	144 (22.0)	168 (25.6)	2.68	1.325	3

Note: N = 656, 5 = Very Aware(VA); 4 = Aware(A); 3= Not Sure (NS); 2= Less Aware (LA); 1= Not Aware (NA); SD = Standard Deviation

Source: Author's Computation, (2024)

Objective 3: Identify the level of usage of BIM across the building stages in the building industry in southwest Nigeria.

4.2.3 BIM Usage (Adoption) by Firms in the Nigerian Building Industry

This section discusses the result of BIM usage (adoption) by firms, the extent of BIM usage, and the building stages at which BIM has been adopted in the Nigerian building industry.

4.2.3.1 Level of BIM usage by Firms in the Nigerian building industry

The adoption of BIM by firms was investigated by asking respondents to indicate their level of BIM usage in their firms on building projects. The question asked for this section was based on a 5-point Likert Scale where 1 represents **Never**; 2 represents **Rare**; 3 represents **Sometimes**; 4 represents **Often**, and 5 represents **Always**. The result is thereby presented in Figure 4.4.

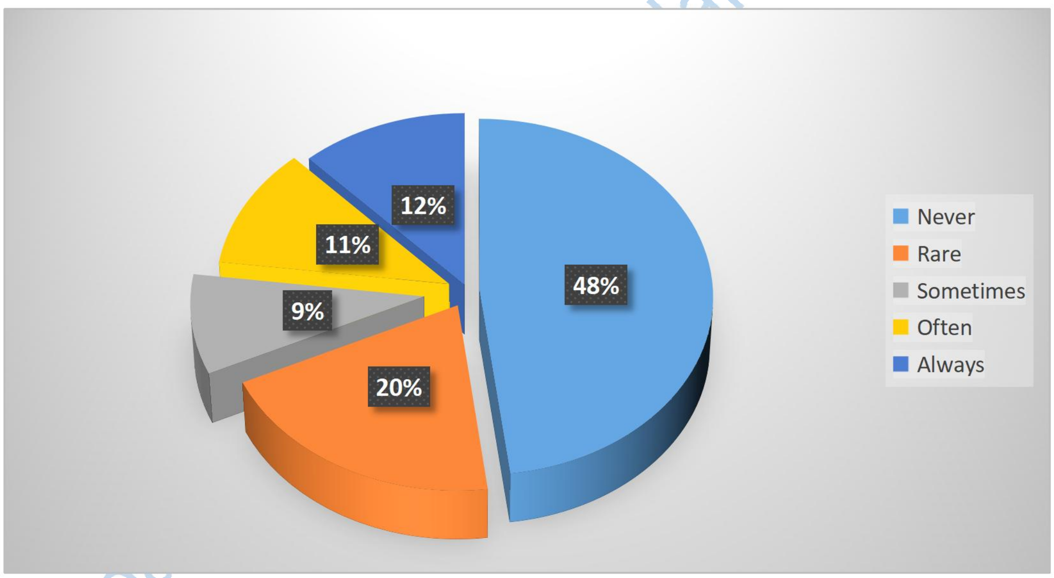

Figure 4.4: BIM Usage among the building industry firms

Source: Author's Computation, (2024)

Based on the responses as show in Figure 4.4, 48% of the sampled firms had never used BIM on any building project and 20% had used it on a rare basis. The study revealed that only

32% of the sample firm have really adopted BIM in excuting their building projects and this represents firms that use BIM sometimes, often and always. Those rates give a drawback indicator of BIM implementation in Nigeria's building industry. This also aligns with a similar study carried out in Federal Capital Development Authority (FCDA), Abuja, Nigeria [16] . Since adequate awareness and knowledge of any innovation have been established to have impact on the adoption of that innovation by the potential adopters [17]. It can then be inferred that the observed high level of awareness and familiarity with BIM and its uses among the firms in the Nigerian building industry might have contributed to the considerable level of adoption (32%) as observed and presented in this study (see Figure 4.4).

Furthermore, Table 4.6 reveals the result of the cross-tabulation of the respondents' firms' level of BIM adoption per location. As presented in Table 4.6, the mean score indicates that BIM has been adopted across the study area however, the extent of adoption was still generally low as all the mean score values were below 3.0.

Table 4.6: Cross-Tabulation of Respondents Level of BIM Usage per Location

Firms' Location	Always	Often	Sometimes	Rare	Never	Mean Score
Ikeja (Lagos)	59(17.6)	10(2.9)	59(17.6)	92(27.5)	115(34.3)	2.89
Ibadan (Oyo)	22(13.8)	19(11.9)	24(15.1)	8(5.0)	86(54.1)	2.52
Abeokuta (Ogun)	13(14.6)	21(23.6)	8(9.0)	5(11.9)	42(47.2)	2.48
Osogbo (Osun)	4(10.7)	4(11.6)	1(2.7)	7(20.6)	18(52.9)	2.39
Akure (Ondo)	2(7.7)	3(11.5)	2(7.7)	2(7.7)	17(52.9)	2.36
Ado Ekiti (Ekiti)	1(7.7)	2(15.4)	0(0)	2(15.4)	8(61.5)	2.22

Note: values in the bracket are percentages

Source: Author's Computation, (2024)

4.2.3.2. Extent of BIM Usage among Firms in the Building Industry in Southwest Nigeria

In order to establish the extent to which BIM had been adopted in the Nigerian building industry, the respondents were asked to select the extent to which their firms have engaged BIM to achieve the activities (of BIM uses) identified from the literature. The result is presented in Table 4.7 based on the types of firms. The result revealed that the top three activities that architects use BIM for in construction exercises are construction planning, visualization, and 3D coordination with mean scores of 3.91, 3.88, and 3.87 respectively (see Table 4.7). This implies that the common BIM-compliant tools used by architects as observed in Table 4.2 which are Revit(99.4%), Autocad(98.8%), Sketchup(87.3), and Archicad (62.0%) are used to achieve ‘construction planning, visualization, and 3D coordination in building projects.

Moreover, the top three activities engineering firms use BIM to perform as seen in Table 4.7 are constructability analysis, construction planning, and construction monitoring with mean scores of 3.86, 3.85, and 3.83 respectively. This also implies that the common BIM-compliant tools used by engineers which are Tekla Structures (97.5%), PowerCivil (72.1%), and Autocad (70.4%) as seen in table 4.2 are used mainly to achieve constructability analysis, construction planning and construction monitoring in building projects. In addion, the study discovered that cost estimation, asset management, and maintenance scheduling with mean scores of 4.12, 3.98, and 3.91

respectively are the three topmost functions that quantity surveing firms use BIM to perform in building processes. This likewise implies that common BIM-compliant tools used by quantity surveying firms as observed in Table 4.2 which are QSCAD (99.3%), MasterBills (98.6%), ArchiFM (72.7%), and Autocad (657.0%) are used to achieve cost estimation, asset management, and maintenance shedulling in building projects.

Furthermore, construction planning, constructability analysis, and sequencing with mean scores of 3.88, 3.85, and 3.81respectively are the top three functions that building contracting firms use BIM to perform in building processes. This infers that the common BIM-compliant tools used by building contracting firms as presented in Table 4.2 which are Autocad (68.5%), ArchiFM (65.7%), and Sketchup (61.8%) are used to achieve construction planning, constructability analysis, and sequencing in building projects.

Table 4.7: Extent of BIM Usage among the Sampled Firms

SN	**Achievements**	**Architectural firm**			**Engineering firm**			**Quantity Surveying firm**			**Building Contracting firm**			Total mean	Total Rank
		Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank		
1	Construction Planning	3.91	0.81	1	3.85	1.13	2	3.65	0.68	4	3.88	0.69	1	3.82	1
2	Visualization	3.88	0.76	2	3.55	0.87	9	2.66	1.00	13	3.77	0.83	4	3.58	2
3	3D Coordination	3.87	0.78	3	3.64	0.84	8	3.00	0.99	9	3.75	0.92	5	3.57	3
4	Cost Estimation	2.94	1.23	14	2.43	1.08	14	4.12	0.98	1	3.52	0.89	6	3.56	4
5	Prefabrication	3.48	1.91	8	3.72	0.97	6	3.55	0.76	5	1.10	1.20	13	2.96	8
6	Constructability Analysis	3.85	0.86	4	3.86	0.86	1	2.75	1.01	12	3.85	0.86	2	3.53	5
7	Sequencing	3.62	0.85	5	3.81	0.89	4	2.93	0.96	10	3.81	0.70	3	2.77	9
8	Construction Monitoring	3.56	0.68	7	3.83	0.90	3	2.88	0.82	11	3.44	0.89	7	3.52	6
9	Clash Detection	3.59	0.71	6	3.75	0.90	5	3.37	0.81	8	3.41	0.99	8	3.51	7
10	Maintenance Scheduling	2.98	1.06	12	3.11	1.00	11	3.91	0.65	3	2.22	0.98	9	2.32	10
11	Fabrication	2.99	0.99	10	3.67	0.87	7	3.52	0.66	6	2.11	1.00	10	2.22	11
12	Asset Management	3.00	0.97	11	3.01	o.77	12	3.98	0.59	2	1.90	0.99	12	2.20	12
13	Building System Analysis	2.98	0.86	9	3.20	0.79	10	3.49	0.67	7	2.10	0.97	11	2.18	13
14	Record Modelling	2.97	0.89	13	2.52	0.90	13	1.17	0.96	14	1.20	0.89	14	1.92	14

Source: Author;s Computation, (2024)

4.2.3.3. BIM Usage among Firms in the Building Industry across the Building Stages

To know the extent of use of BIM across the stages of work in the building industry, the respondents were asked to select stage(s) wherein their firms have engaged BIM in building projects and the result is presented in Figure 4.5. The study found that although it appears that the respondents use BIM across the various stages of project execution, there is a predominant use of BIM at the design stage (69%). This is followed by the use of BIM at the construction stage (19%) as well as the maintenance/renovation stage (12%) as illustrated in Figure 4.5. However, despite the enormous benefits of BIM at the operational stage of buildings, as noted by [18], it is obvious from this study that BIM is rarely used in the operation stage of constructed facilities in the study area.

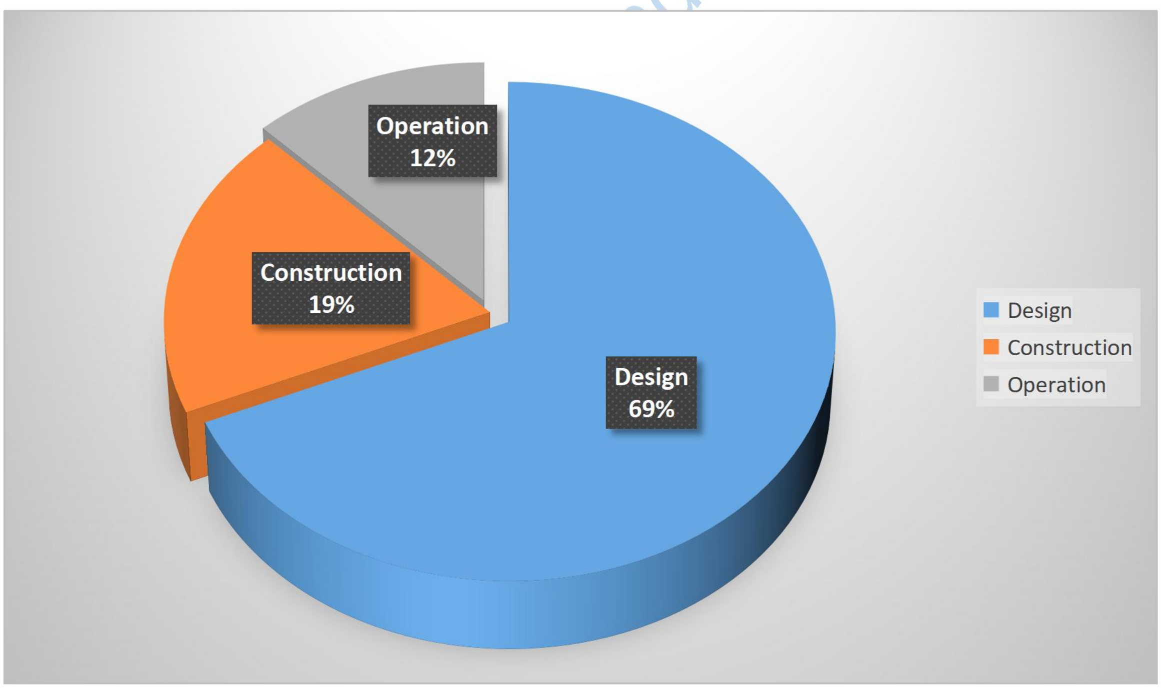

Figure 4.5: BIM Usage across building stages

Source: Author's Computation, (2024)

The study went further to test how the annual turnover of the firms could affect BIM usage. The descriptive statistics show that mean values ranged from 3.06 to 25.73 as shown in Table 4.8. This is further illustrated in Figure 4.6; the breakdown of results shows a kind of consistent pattern as the mean scores tended to increase with the annual turnover of the firms. The lowest mean score of 3.06 was obtained for those firms with annual turnover < 1M while those with >250M turnover recorded the highest (25.73). The ANOVA results show that a significant difference exists in the level of usage of BIM among firms' respondents based on the annual turnover of the firms ($F= 6.626$, $p<0.05$). Going by this result, it could be said that the annual turnover of the firms influences the level of usage of BIM in the building and construction industry in Nigeria. Those firms with <1M annual turnover have low levels of BIM usage compared to the firms with an annual turnover of 101 – 250M and > 250M which have high levels of BIM usage.

Table 4.8: Usage of BIM with Respect to Firms' Annual Turnover

Firm type	Mean	Std. Deviation	F	Sig
< 1M	3.06	0.70290		
1 – 10M	5.80	0.85111		
11 – 50M	7.50	1.13228	6.626	0.018
51 – 100M	11.91	0.52705		
101 – 250M	13.36	0.98577		
>250M	25.73			
Average Mean	11.23			

Source: Author's Computation, (2024)

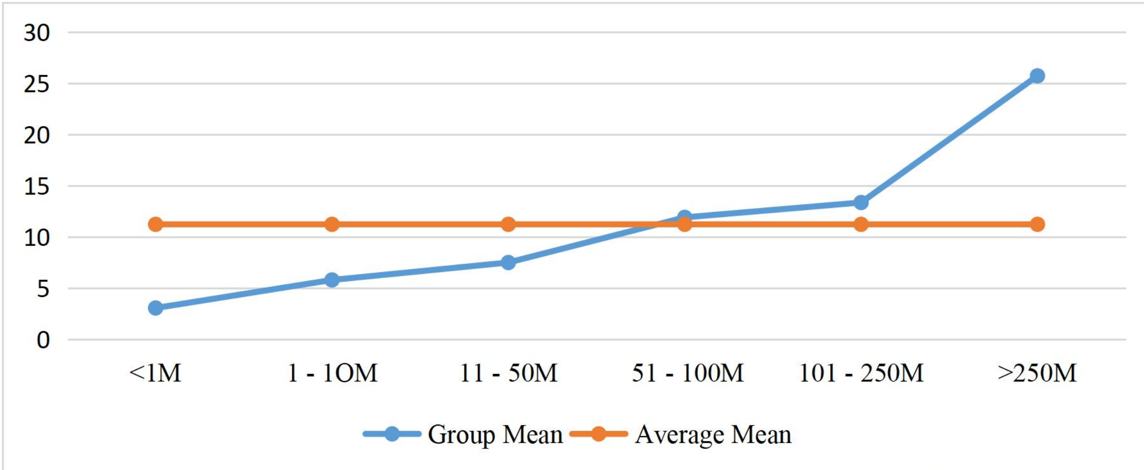

Figure 4.6: Usage of BIM with Respect to Firms' Annual Turnover

Source: Author's Computation, (2024)

Objective 4: evaluate the factors that influence the adoption of BIM in the building industry in southwest Nigeria.

4.2.4 Factors that influence the adoption of BIM in the Nigerian building industry.

This section presents respondents' rating of the barriers that can limit the adoption of BIM and the Critical Success Factors (CSF) that can drive the adoption of BIM in the Nigerian building industry

4.2.4.1 Barriers to BIM adoption in the Nigerian building industry

Barriers have been identified as factors that can inhibit the adoption of any innovation. These barriers could be of different categories depending on the innovation to be adopted [19]. The review of the literature revealed some barriers that could hinder the adoption of BIM in countries around the world. In this study, 39 barriers to the adoption of BIM were within the context of the Nigerian building industry. Factor analysis was undertaken on the identified

39 barriers to BIM adoption in the Nigerian building industry and was also checked against Kaiser-Meyer-Olkin (KMO) and Barlett's test of specificity. Thus, as shown in Table 4.9, the data obtained were confirmed satisfactory with a Kaiser-Meyer-Olkin (KMO) value of 0.906, consistent with the value of 0.6 as recommended by Kaiser (1974) and Barlett's test of specificity value of 0.000 (less than .05) with an approximate chi-square value = 1399.054, and df = 190. Notable earlier researchers in BIM studies supported this approach [20, 21, 22,] .

Table 4.9: KMO and Bartlett's Sphericity Test

Kaiser-Meyer-Olkin measure of sampling adequacy		0.906
Bartlett's test of Sphericity	Approx. Chi-Square	1399.054
	Df	190
	Sig	0.000

Source: Author's Computation, (2024)

In determining the number of factors to be extracted for the rotated factor analysis an initial non-rotated factor analysis was conducted using the principal component analysis (PCA) method and five major components with eigenvalue greater than 1 were extracted (Table 4.10). To ascertain if the extracted components should be selected for the rotated PCA, Monte Carlo parallel analysis was conducted randomly for the 39 barriers investigated in this study as presented in Table 4.11. It was observed that the values of the five categories extracted from the PCA on barriers to BIM adoption in the Nigerian building industry were all greater than their corresponding values produced in the parallel analysis.

Table 4.10: Initial Non-Rotated Total Variance Explained

Component	Initial Eigenvalues			Extraction of Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.487	39.192	39.192	3.010	21.503	21.503
2	3.125	12.520	51.712	2.783	19.878	41.381
3	1.753	11.029	62.741	2.214	15.811	57.192
4	1.544	7.155	69.896	1.779	10.704	66.896
5	1.202	6.862	76.758	1.312	9.862	76.758
6	.988	2.880	79.638			
7	.921	2.270	81.908			
8	.897	1.921	83.839			
9	.869	1.632	85.471			
10	.860	1.510	87.031			
11	.844	0.911	88.721			
12	.818	0.827	88.920			
13	.770	0.839	89.123			
14	.728	0.860	89.532			
15	.718	0.844	90.242			
16	.712	0.858	90.653			
17	.689	0.760	91.427			
18	.608	0.778	9.861			
19	.555	0.788	92.222			
20	.512	0.792	92.821			
21	.502	0.619	93.411			

22	.497	0.612	93.784
23	.489	0.515	93.855
24	.452	0.510	94.213
25	.432	0.502	94.517
26	.422	0.492	94.721
27	.401	0.489	95.515
28	.399	0.432	95.942
29	.372	0.428	96.37
30	.312	0.427	96.797
31	.301	0.422	97.219
32	.272	0.419	97.638
33	.270	0.400	98.038
34	.268	0.397	98.435
35	.265	0.369	98.749
36	.232	0.314	99.118
37	.222	0.301	99.515
38	.189	0.208	99.230
39	.172	0.211	100.000

Source: Author's Computation, (2024)

Table 4.11: Monte Carlo PCA for Parallel Analysis

Factors	Random Eigenvalue	Standard Dev
1	1.4282	0.0462
2	1.3427	0.0392
3	1.2809	0.0300
4	1.2226	0.0299
5	1.1702	0.0284
6	1.1164	0.0275
7	1.0728	0.0268
8	1.0272	0.0237

9	0.9856	0.0202
10	0.9439	0.0220
11	0.9018	0.0224
12	0.8616	0.0217
13	0.8188	0.0188
14	0.7803	0.0211
15	0.7319	0.0220
16	0.7252	0.0227
17	0.6974	0.0232
18	0.6277	0.0240
19	0.6121	0.0285
20	0.596	0.0260
21	0.556	0.0252
22	0.525	0.0243
23	0.501	0.0222
24	0.492	0.0216
25	0.487	0.0210
26	0.459	0.0201
27	0.444	0.0189
28	0.423	0.0185
29	0.400	0.0191
30	0.398	0.0187
31	0.382	0.0200
32	0.373	0.0214
33	0.361	0.0233
34	0.322	0.0213
35	0.310	0.0233
36	0.297	0.0290
37	0.277	0.0267

38	0.268	0.0249
39	0.247	0.0189

Source: Author's Computation, (2024)

Hence, the rotated PCA was limited to five significant components. The percentage of explained variance by the five components was 76.76% (Table 4.10), with factors 1,2,3,4, and 5 accounting for 39.19%, 12.52%, 11.03%, 7.12%, and 6.86% respectively, before rotation.

After the rotated PCA was conducted, using Varimax rotation, the percentage variance accounted for by factors 1, 2, 3, 4, and 5 were 21.50%, 19.88, 15.81%, 10.70%, and 9.86%, respectively. This suggests that, while the distribution differed from the baseline variance accounted for before rotation, the overall variance of the five factors remained constant after rotation; only the distributions of the factors loaded into each factor varied, as shown in Table 4.12. This finding also demonstrated that factor 1 explained 21.50%of the barriers that influence firms' BIM adoption in the Nigerian building sector, whereas factors 2, 3, 4, and 5 accounted for 19.88%, 15.81%, 10.70%, and 9.86%, respectively. The five main factors extracted are interpreted as follows:

(1) Factor 1: Human factors group

(2) Factor 2: Management factors group

(3) Factor 3: Technological factors group

(4) Factor 4: Project factors group

(5) Factor 5: External factors group

Table 4.12: Rotated Component Matrix for BIM Adoption Barriers

Factors	Barriers to BIM Adoption	Component loading for each category		
	Ignorant of BIM usefulness	0.758		
	Lack of Experience and Skills	0.734		
	Unwillingness to use BIM	0.724		
	Absence Work motivation	0.718		
	Personal Incompetency	0.704		
	Lack of Interest	0.704		
	Negative Perception of Ease of Use	0.690		
	Financial resources		0.738	
	Ignorance of benefits of BIM for organization		0.730	
	Unavailability of BIM users		0.712	
	Organizational readiness		0.710	
	Lack of Capacity to use information technology		0.706	
	Unavailability of technical infrastructure		0.698	
	Perceived risks		0.692	
	Lack of Manager's support		0.686	
	Organization's culture		0.676	
	Organization's capacity		0.674	
	Organization's policies		0.672	
	Speed of BIM tools			0.750
	Technology Quality			0.738
	Functionality			0.720

Feasibility using BIM	0.716		
IT support	0.716		
Result demonstrability	0.716		
BIM complexity	0.714		
Accessibility	0.494		
Trialability	0.484		
Procurement methods	0.450		
Project scale		0.716	
Project requirements		0.716	
Stakeholders' awareness		0.714	
Project complexity		0.700	
Stakeholders interaction		0.700	
Government supports			0.724
BIM standards			0.696
BIM instructions			0.696
BIM providers			0.686
Competition levels			0.470
Laws and policies			0.356

Source: Author's Computation, (2024)

Moreover, to identify which of the barriers the respondents believed inhibit BIM adoption in the Nigerian building industry they (the respondents) were asked to indicate their levels of agreement with the 39 barriers to BIM adoption identified from the literature reviewed. The results are presented in Tables 4.10, 4.11, and 4.12.

4.2.4.1.1 Human Factors Group

This factor amounts to 21.50% of the total variance of barriers to BIM adoption in the Nigerian building industry. This factor has seven main items as follows: ignorance of BIM usefulness; lack of experience and skills; unwillingness to use BIM; lack of work motivation; personal incompetency; lack of interest; and negative perception of ease of use. The surveyed respondents ranked "ignorance of BIM usefulness" in the first place with a mean score = 3.79, proving that it has the greatest influence on BIM adoption in the study area. This result is in line with some previous studies' opinions, which indicated that ignorance of BIM usefulness is a prerequisite factor for users to accept BIM software [23, 24. 25]. Ignorance of BIM usefulness is the most critical barrier to the behavioral intention of using BIM studies [26, 27, 28, 29, 30]. When respondents observed that BIM was useful, their attitude towards the use of BIM increased and their intention to use BIM increased significantly [31]. The " Lack of experience and skills" factor is the second critical factor in the human factor group, with a mean score = 3.67. This ranking was supported by a study that explained that limited experience and skills in new technology were mostly affected by BIM intentions to use just right after a lack of training and lack of self-efficacy [32]. However, this finding contradicts the result of another study in which, the experience of human resources was ranked 41 over 45 factors [33]. In this regard, "experience and skills" do not frequently affect the intention to use BIM of an individual. With a mean score = 3.62 "unwillingness to use BIM" is ranked third in this group, which shows that this factor has a high impact on BIM adoption among firms in the study area. This was proved by a study, which stated that staff willing to improve their market competitiveness by playing a proactive role in learning BIM software. Another factor is "lack of work motivation" (mean score = 3.59), which ranked fourth in this group, indicating that motivation plays an important role in learning new technology. "Personal incompetency", "lack of interest" and "negative perception of ease of use" with mean scores of 2.52, 2.52, and 2.45 respectively, have a low effect on BIM adoption.

In cases where the mean scores are above 3.0, it implies that the factors are critical barriers to the adoption of BIM in the Nigerian building industry, while those below 3.0 are not critical barriers to the adoption of BIM in the industry. Based on the interpretation of the framework, it is evident that 'ignorance of BIM usefulness''; ''lack of experience and skills''; ''unwillingness to use BIM''; and ''lack of work motivation''; are critical barriers to the adoption of BIM by firms in the study area under the human factor group.

Table 4.13. Ranking of Factors under the Human Group

Factors	Mean	Std. Deviation	Rank
Ignorance of BIM usefulness	3.79	0.977	1
Lack of experience and skills	3.67	0.898	2
unwillingness to use BIM	3.62	0.966	3
Lack of work motivation	3.59	1.057	4
Personal incompetency	2.52	0.934	5
Lack of interest	2.52	0.967	5
Negative perception of ease of use	2.45	0.946	7

Source: Author's Computation, (2024)

4.2.4.1.2 Management Factors Group

This factor amounts to 19.88% and financial resources are in the first place in this group with a mean score = 3.69 indicating that the huge financial implication of procuring BIM software and the associated training of staff required is considered a major barrier to BIM adoption in Nigeria building industry firms. Also, as demonstrated in Table 4.14, “Lack of awareness of BIM’s full potential” is in second place in this group with a mean score = 3.65, proving that this factor has a significant effect on the application of BIM in a project. This ranking was further supported by study [34], which stated that lack of awareness of BIM’s full potential is one of the three main factors affecting the AEC industry in BIM adoption, along with external forces and internal readiness. With a mean score = 3.56, “unavailability of BIM users” ranked third over the 11 management factors group, indicating that skilled staff who can handle BIM tools is important in the decision to use BIM software by firms. This ranking is in line with some previous studies, which proved that the availability of trained professionals to handle BIM tools was found to be the most significant driver of BIM application [35, 36, 37, 38]. For example, it was stated that few technically trained employees would assist the adoption of BIM for organizations [39]. The unavailability of BIM users had also been identified as the foremost barrier to the introduction of BIM in the USA [40] and one of the major obstacles in the UK [41]. As for developing countries, a lack of trained professionals was ranked fifth according to the significant study context of Nigeria [42]. By contrast, a study indicated that the number of BIM experts and technical staff had a low influencing degree to aid the adoption of BIM technology as it mainly changed the workflow and pattern of the organizations and had impacts on some human factors (i.e., perceived ease of use, perceived usefulness and intention to use) [43]. In this regard, the unavailability of skilled staff had significant influence on BIM implementation in many countries.

The next three influencing factors are “Organizational readiness,” “Lack of capacity to use information technology” and “unavailability of technical infrastructure” with the mean score = 3.00, 3.01, and 3.02 respectively. Although they ranked fourth, fifth, and sixth, their differences are not significant (0.001), which indicates that these three factors’ influences were similar and slightly significant to the adoption of BIM. The mean scores of the last five factors (Perceived risks = 2.46, Lack of manager’s support = 2.43, Organization’s culture = 2.38, Organization’s capacity = 2.37, and Organization’s policies = 2.36) are below 3.0 critical standard. indicating that these factors have a low influence on the adoption of BIM.

Table 4.14. Ranking of Factors under Management Group

Factors	Mean	Std. Deviation	RII	Rank
Financial resources	3.69	0.900	0.738	1
Lack of awareness of BIM’s full potential	3.65	1.000	0.730	2
Availability of BIM users	3.56	0.890	0.712	3
Organizational readiness	3.00	0.972	0.710	4
Capacity to use information technology	3.01	1.011	0.706	5
Availability of technical infrastructure	3.02	0.913	0.698	6
Perceived risks	2.46	0.979	0.692	7
Manager’s support	2.43	0.952	0.686	8
Organization’s culture	2.38	0.926	0.676	9
Organization’s capacity	2.37	0.932	0.674	10
Organization’s policies	2.36	1.002	0.672	11

Source: Author’s Computation, (2024)

4.2.4.1.3 Technological Factors Group

This factor has 15.81% (see Table 4.10) of the total variance of barriers to BIM adoption in the study area. The ranking of 10 factors under the technological group is shown in Table 4.15. With a mean score = 3.75, "interoperability of BIM tools" was ranked first in this group, which shows that this factor is a powerful determinant and has a very high effect on BIM usage. This is because the participants believed that speed was the most outstanding and obvious advantage of BIM compared to traditional methods. "Technology quality" (mean score = 3.69) was ranked second in this category, proving that this factor has a significant influence on BIM application. "Functionality" was the third element driving BIM adoption with a mean score = 3.60. This factor was also mentioned in a study as one of the two main areas referred to BIM adoption, including technical tools—functional requirements and needs, and the non-technical strategic issues [21].

"Feasibility using BIM," "IT support," and "result demonstrability" were evaluated to have the same effect on BIM adoption as in the respondents' opinion, with a mean score = 3.58. They were all ranked fourth in this group and tenth in the overall ranking, indicating that the three factors have an important influence on the introduction of BIM technology. This was buttressed by a study that stated that poor IT conditions were a huge constraint to technology adoption activity [44]. Meanwhile, "result demonstrability" was mainly recognized as the ability of BIM in visualization and proved to be the significant advantage of BIM software that drove respondents to try using BIM Okereke et al., (2021). Furthermore, it was stated in the prior study that the effortless observability of BIM to organization top management is a contributing factor to BIM adoption [45]. "BIM complexity" with a mean score = 3.57 is in the seventh place of this group, indicating that this factor has a moderate impact on BIM adoption.

The other factors in this group are “accessibility,” “trialability,” and “procurement methods” with mean scores ranging from 2.47 to 2.25, ranking eighth, ninth, and tenth respectively in this category. This proves that these factors have a low influence on the application of BIM.

Table 4.15. Ranking of Factors under Technological Group

Factors	Mean	Std. Deviation	Rank
Interoperability of BIM tools	3.75	0.919	1
Technology Quality	3.69	0.936	2
Functionality	3.60	0.922	3
Feasibility using BIM	3.58	0.970	4
IT support	3.58	0.830	4
Result demonstrability	3.58	0.963	4
BIM complexity	3.57	0.918	7
Accessibility	2.47	0.913	8
Trialability	2.42	0.937	9
Procurement methods	2.25	1.006	10

Source: Author’s Computation, (2024)

4.2.4.1.4 Project Factors Group

This factor accounted for 10.70% (see Table 4.10) of the total variance of barriers to BIM adoption in the Nigerian building industry. The results of Table 4.16 indicate that five factors of the project group have been ranked by mean score. "Project scale" and "project requirements" with a mean score = 3.58 were ranked the first in this group, indicating that the two factors have a similar effect on BIM adoption and their influence is moderate. These were closely followed by "stakeholders unawareness' with a mean score = 3.57. This ranking is in line with the previous study, which ranked this factor fifth out of 10 drivers, indicating that the unawareness of the technology among industry stakeholders was found to be a critical barrier to BIM adoption in Nigeria [46]. "Project complexity" and "stakeholders" interaction' shared the same mean score value of 3.50 and were assessed to be limiting barriers to BIM adoption.

Table 4.16 Ranking of Factors under Project Group

Factors	Mean	Std. Deviation	Rank
Project scale	3.58	0.996	1
Project requirements	3.58	0.957	1
Stakeholders' unawareness	3.57	0.965	3
Project complexity	3.50	1.043	4
Stakeholders interaction	3.50	1.012	4

Source: Author's Computation, (2024)

4.2.4.1.5 External Factors Group

Table 4.17 indicates the ranking of six factors related to external drivers. With a mean score = 3.72, "lack of government support" was ranked first in this group, which shows that this factor is a critical barrier to BIM adoption. Also, the surveyed respondents ranked "BIM standards" and "BIM instructions" (mean score = 3.48) in the second position in this group.

Some previous research has proven the importance of the mentioned factors in the adaptability of BIM [47, 48, 49]. For instance, a study stated that the lack of BIM standards/guidelines was the reason why most BIM potential remains untapped in Anambra State Nigeria [50]. With mean score = 3.43, "BIM providers" followed closely to the previous factors in terms of influence level on BIM application. The remaining factors under the external group are "competition levels," and "laws and policies," with mean scores of 2.55 and 2.28 respectively, were ranked at the end of this group, which reveals that these factors have a low effect on the application of BIM.

Table 4.17. Ranking of Factors under External Group

Factors	Mean	Std. Deviation	Rank
Lack of Government supports	3.72	1.052	1
BIM standards	3.48	0.967	2
BIM instructions	3.48	0.940	2
BIM providers	3.43	0.938	4
Competition levels	2.55	0.969	5
Laws and policies	2.28	1.038	6

Source: Author's Computation, (2024)

4.2.4.2 Critical Success Factors (CSFs) for BIM Adoption by Firms in the Nigerian Building Industry

Table 4.15 indicates the ranking of the ten identified success factors for BIM adoption in the Nigerian building industry. Based on each firm category, the findings are as follows:

Architectural firms: The top five ranked from the respondents in architectural firms include incorporation of BIM to the academic curriculum; improvement of BIM awareness and understanding; reduction in cost of implementing BIM; provision of training by employers; and provision of appropriate technology and infrastructure with their mean values of 4.71, 4.64, 4.47, 4.34, and 4.32 respectively.

Structural engineering firms: The top five ranked structural engineering firms are: improving BIM awareness and understanding; incorporating BIM into academic curriculum; outsourcing BIM experts; providing training by employers; and developing BIM guidelines with their respective mean values of 4.47, 4.39, 4.35, 4.35, and 4.35 respectively.

Quantity surveying firms: The top five ranked from quantity surveying firms include the provision of training by employers; incorporation of BIM into the academic curriculum; improvement of BIM awareness and understanding; reduction in the cost of implementing BIM; and government legislation supporting the use of BIM with the mean values of 4.78, 4.73, 4.72, 4.64, and 4.55 respectively.

Building and Contracting firms: The top five ranked from structural building contracting firms are the incorporation of BIM into the academic curriculum; provision of training by employers; improve of BIM awareness and understanding; reduction in cost of implementing BIM; outsourcing of BIM experts; and government legislation supporting the use of BIM with their respective mean values of 4.72, 4.48, 4.41, 4.31, and 4.29 respectively.

Table 4.18 Critical Success Factors (CSFs) for BIM Adoption by Firms in the Nigerian Building Industry

Critical factors	**Architectural firm**			**Engineering firm**			**Quantity Surveying firm**			**Building Contracting firm**			Total mean	Total Rank	Kruskal Wallis sig
	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank			
Incorporation of BIM into academic curriculum	4.71	0.61	1	4.39	1.10	2	4.73	0.59	2	4.72	0.66	1	4.64	1	0.743
Improve BIM awareness and understanding	4.64	0.66	2	4.47	0.90	1	4.72	0.65	3	4.41	0.71	3	4.56	2	0.393
Outsourcing BIM experts	3.99	0.86	9	4.35	0.90	3	4.36	0.75	9	4.29	0.93	5	4.25	8	0.184
Provision of training by employers	4.34	0.80	4	4.35	0.90	4	4.78	0.53	1	4.48	0.87	2	4.49	3	0.030*
Government Legislation supporting the use of BIM	4.17	0.91	8	4.22	0.87	7	4.55	0.69	5	4.22	0.83	6	4.29	6	0.137
Developing BIM guidelines	4.22	0.78	7	4.35	0.90	5	4.52	0.61	6	4.16	0.89	7	4.31	5	0.190
Reduction in cost of implementing BIM	4.47	0.78	3	3.85	0.79	10	4.64	0.68	4	4.31	0.85	4	4.32	4	0.068
Setting up BIM council	3.89	0.99	10	4.09	0.82	8	3.93	0.96	10	3.98	1.22	10	3.97	10	0.821
Compulsory use of BIM for all procurement and contract	4.24	1.01	6	4.35	0.90	6	4.37	0.80	8	4.16	1.20	8	4.28	7	0.589
Provision of appropriate technology and infrastructure	4.32	0.87	5	4.00	0.89	9	4.49	0.67	7	4.00	0.90	9	4.20	9	0.149

*p-value <0.05

Source: Author's Computation, (2024)

Similarly, the overall ranking of the ten identified success factors of BIM adoption in Nigerian building firms indicated that the overall mean values range from 3.97 to 4.64; this implied that all the ten identified success factors are considered critical. In addition, the overall top five ranked success factors of BIM adoption in building industry firms are: incorporation of BIM to academic curriculum; improve BIM awareness and understanding; provision of training by employers; reduction in cost of implementing BIM; and developing BIM guidelines with their total mean score values of 4.64, 4.56, 4.49, 4.32, and 4.31 respectively. These study findings confirm the existing literature. For instance, a study identified collaboration, training and promotion as the ways forward for BIM implementation in Hong Kong [51]. Also a study claimed that BIM should be made compulsory for all procurement processes and contracts, and setting up BIM council [52]. In addition, the results of Kruskal–Wallis test revealed that except one (out of 10) identified success factor of BIM adoption; there is no statistically significant difference in the perceptions of the four respondents' groups (firms).

Objective 5

4.5 Significant BIM benefits in the Nigerian building industry.

Table 4.19 displays the findings of the data analysis conducted on the benefits of BIM adoption in the building industry. The main benefits of using BIM in the building industry are: minimizing errors and mistakes (relative importance index RII=0.956), improving project quality (RII=0.962), and reducing rework in construction (RII=0.976). improved multi-party communication and collaboration (RII=0.947), improved project documentation (RII=0.944), improved clash detection (RII=0.953), shortened construction time (RII=0.948), improved efficiency and productivity (RII=0.939), decreased project costs (RII=0.933), and minimized disputes and conflicts (RII=0.932 While the least important benefits of BIM adoption based on this study are; facilitating asset and equipment maintenance and management (RII=0.867); increasing energy efficiency (RII=0.867); providing accurate and up-to-date information (RII=0.862); monitoring and tracking construction progress (RII=0.855); enhancing team-building abilities (RII=0.853); and creating space for more off-site materials/component prefabrication (RII=0.836). Information access is quick and dependable (RII=0.823), enhances facility operation and maintenance decision-making (RII=0.820), facilitates more precise and quick project cost and time estimation (RII=0.818), and permits flexible and sustainable design (RII=0.802).

Ultimately, these factors continue to reflect the essential role that BIM adoption plays in building projects, regardless of how these are ranked in relation to one another. This is predicated on the range of RII values, with an average of 0.895 (89.50%) a maximum of 0.976 (97.60%), and a minimum of 0.802 (80.20%). The benefits of BIM in construction are substantial, and if resources allow, it has been demonstrated that these cutting-edge tools are used in the completion of every construction project. This study's findings are consistent with the documented literature that has already been published, including works by [53, 54, 55. 56., 57, 58]. One of the greatest problems confronting the construction industry is 'rework'. Rework has been blamed for some of the issues related to cost overruns, time overruns, poor quality, increase waste, disputes, and loss of profits. BIM is found to minimise this problem on construction projects as indicated by [59.].

BIM allows for the visualisation of the proposed building as it provides a digital model of the object. Clashes in the building services and the system could be located and eliminated to improve project performances with regards to time, cost, quality, among others [60, 61]. BIM has transformed the way construction projects are executed, according to [62]. The main benefits of BIM include cost savings, less design conflict, improved cooperation, easier and more informed decision making, and enhanced project performance. In line with the results of this investigation, a study stated that the primary advantages of BIM are its propensity to lower project length and expense [63].

One of the innovations in a technology revolution that aims to lessen faults and inaccuracies in project documentation and designs is BIM. Changes and rework that could affect project baselines like the time and budget are minimized or eliminated when faults in design and other contract papers are reduced or eliminated. Moreover, modifications and rework during construction lead to waste generation that has an adverse effect on the environment. The study's conclusions about how BIM can cut down on project length, cost, rework, and errors are consistent with the submission of [64].

To determine if there is a significant difference in the view of the firms'respondents regarding the rating of the assessed variables, The Kruskal– Wallis test was conducted. It is obvious from Table 4.19 that the p-value of 22% (7) variables are below the significant value of 0.05. This means that the sampled firms hold a divergent opinion on the rating of the affected benefits of BIM. These variables in which the perception of the respondents differ are; Improve services delivery (RII=0.914, Sig=0.000), provides a digital model that can be utilized throughout the building life cycle (RII=0.894, Sig=0.017), effective management of project resources procurement and storage (RII=0.885, Sig. =0.000), facilitate equipment and asset maintenance and management (RII=0.867, Sig.=0.001), Provision of accurate and updated information (RII=0.862, Sig.=0.016), monitor and track progress during construction (RII=0.855, Sig.=0.003), improve decision making at the operation and maintenance of a facility (RII=0.820, Sig.=0.014). The difference in rating by the firms does not invalidate these roles played by BIM in the building industry. The difference in the ranking of the affected variables by the firms showed the different levels of knowledge and usage by the professionals and their employers. It further reflects the unevenness in the usage and knowledge of BIM in the building industry of developing countries. It also shows the relative application of BIM at various stages of construction project development. However, 25 (78%) of the assessed variables had their p-value of greater than 0.05, implying that there are no significant statistical difference in the rating by the respondents. The firms'respondents have a convergent opinion on these variables. It can be concluded that the construction industry stakeholders agree on the assessed benefits of BIM, especially as it has to do with its adoption in builing industry.

Table 4.19 - Benefits of BIM Adoption in Construction

S/N	Variables	RII	Rank	Kruskal Test	Wallis
				Chi-Square	P-value
1	Improve project design	0.915	13	7.657	0.054
2	better clash detection	0.953	4	3.013	0.390
3	better coordination	0.871	20	1.205	0.974
4	Reduce Rework in Construction	0.976	1	3.557	0.313
5	better synchronization	0.870	21	6.733	0.081
6	better projects sequencing	0.867	22	7.104	0.069
7	give room for more off-site materials/components prefabrication	0.836	28	2.284	0.516
8	enable visualization of the built environment	0.891	17	4.903	0.179
9	improves health and safety	0.923	12	4.862	0.095
10	Allow for flexibility and sustainable design	0.802	32	0.474	0.407
11	facilitate equipment and asset maintenance and	0.867	22	15.920	0.001*

	management				
12	Provides a digital model that can be utilized throughout the building life cycle.	0.894	16	10.249	0.017*
13	more accurate and speedy estimation of project cost and time	0.818	31	4.363	0.225
14	improvement in energy efficiency	0.867	22	7.096	0.069
15	improve resources planning and sequencing	0.876	19	4.203	0.240
16	effective management of project resources procurement and storage	0.885	18	18.968	0.000*
17	allows for effective and efficient utilization of site	0.924	11	0.962	0.294
18	Improves efficiency and productivity	0.939	8	0.947	0.814
19	Improves decision-making at the operation and maintenance of a facility.	0.820	30	10.579	0.014*
20	Access to information is fast and reliable	0.823	29	7.391	0.060
21	Provision of accurate and updated information	0.862	25	10.341	0.016*
22	Improving team-building skills	0.853	27	0.615	0.720
23	monitor and track progress during construction	0.855	26	13.847	0.003*
24	Improve services delivery	0.914	15	21.279	0.000*
25	Project cost reduction	0.933	9	7.293	0.063
26	Reduced Construction Time	0.948	5	3.456	0.326
27	Improve project Quality	0.962	2	4.049	0.088
28	Improve project documentation	0.944	7	1.378	0.711
29	improve multi-party communication and collaboration	0.947	6	5.381	0.146
30	Minimize Errors and mistakes	0.956	3	1.924	0.588
31	Constructability improvement	0.915	13	0.907	0.819
32	Minimizes disputes and conflicts	0.932	10	0.738	0.864

*p-value <0.05

Source: Author's Computation, (2024)

The level of significance of the respondents' perception was further assessed by combining the general rating of BIM benefits. The Kruskal-Wallis Test result in Table 4.20 shows that there is no significant difference in the view of the firms' respondents regarding the rating of the assessed benefits of BIM adoption. The p-value of 0.178 obtained for the variables assessed is greater than the significant value of 0.05. The participants' opinions converge on the assessed variable, and this implies that the building industry stakeholders agree on the potential benefits of BIM adoption in the construction industry of Nigeria and, by extension other developing countries of Africa which have similar economic terrain.

Table 4.20 - Kruskal-Wallis Test

Variable	Respondents (Firms)category	N	Mean Rank	df	Chi-Square	Asymp. Sig.
	Architecture	173	91.40			
	Engineering	162	79.06			
Benefits of BIM adoption	Building and Consulting	178	55.39	3	5.221	0.178
	Quantity Surveying	143	63.58			
Total		656				

*p-value <0.05

Source: Author's Computation, (2024)

4.3 Discussion of Findings

Demographic Characteristics

The results of the demographic characteristics of the firms show diversity in types, locations, years in operation (age of the firm), area of specialization, annual turnover, and work experience of the respondents. The study population comprised architectural firms, structural engineering, building contracting, and quantity surveying firms. The study discovered that most of the sampled firms were based in Lagos (51.1%). This might be because Lagos, the most populous and commercialized city in Nigeria, provides a ready market for services provided by firms in the building industry to meet the daily demand for more accommodation, commercial buildings, and all other types of infrastructure to accommodate the city's growing population. Contrarily, Osogbo (Osun State) has relatively few building industry firms at 5.2%, followed by Akure (4.0%), and then Ado (2.0%), with the lowest number of firms. This implies that the need and demand for building firms' services in these cities are probably low.

Moreover, the result of the study showed that the respondents' experience was impressive as the study had a reasonable percentage of them who had been in the building industry for years. For instance, about 62.6.8% had worked in the building industry for more than 10 years, and most respondents' project specializations are residential and all building types, accounting for 21.7 and 67.5% of responses, respectively. This inferred that the respondents are highly experienced and have played significant roles in their firms. Their opinion on the survey's relevance is significant because of these qualities, making it confidently reliable.

BIM Software Applications and their Relative Usage in the Nigeria building industry

A total of fourteen common BIM software programs were examined. The result revealed that the level of awareness of the common BIM software programs among the building industry firms in southwest Nigeria was above average. For instance, 42.1% of respondents were aware of Tekla Structures; 86% were aware of Archicad; 47.7% were aware of ArchiFM; 8.2% were aware of Green Building Studio; 69.4% were aware of Masterbill; 75% were aware of Revit Architecture; 85.1% were aware of Sketch-Up; 74.7 were aware of Power Civil; 10.1% were aware of Digital Project; 92.1 were aware of Navistwork Manager; 99.7% were aware of AutoCAD; 38% were aware of VICO Software; 92.1% were aware of Bentley BIM Suite and 89.9% were aware of QS CAD.

However, the extent of usage of these software was found to be low as their usage was not commensurate with the awareness level. For instance, 17.1% of respondents used Tekla Structures; 36% used Archicad; 37.2% used ArchiFM; 2% used Green Building Studio; 21% used Masterbill; 64.8% used Revit Architecture; 59% used Sketch-Up; 19.4% used Power Civil; 1.1% used Digital Project; 55.9% used Navistwork Manager; 95% used AutoCAD; 9% used VICO Software; 10.1% used Bentley BIM Suite and 25% used QS CAD. This study conforms with previous studies which indicated that the professionals in the building firms are well aware of BIM-compliant software although awareness does not necessarily reflect active usage [65, 66.67]. However, the result of this study contradicted what was found by another study which stated there was a high level of use of BIM software packages in the Nigerian building industry [68].

The lack of corresponding usage of BIM-compliant software as discovered in this study could be a result of the obstacles preventing the adoption of BIM as mentioned by a study [69]. Additionally, a study claimed that because of staff members' inadequate training and software package bugs, most professionals in Nigeria's building industry have also been unable to employ BIM-compliant software [70].

Furthermore, data from the present study show that AUTOCAD, Revit Architecture, and SketchUp were the most often utilized software programs. The majority of survey respondents were architects, engineers, building contractors, and quantity surveyors, and these professionals primarily use AUTOCAD, Autodesk Revit Structure, and SketchUp so it was not surprising that these programs emerged as the most widely used BIM packages in this research. These software programs have also been found to be CAD tools that enable architects to create architectural plans, arrange layouts, create conceptual elements, and present finished design drawings to clients on a computer before they are presented in person [35, 71, 72].

Awareness Level of BIM Uses Across the Building Stages

A total of fourteen BIM uses across the building stages were identified in the literature. The study examined the awareness level of these BIM uses in the Nigerian building industry. The Mean Score ranking was adopted to assess the awareness level of BIM Uses among the building industry firms at different stages of the project lifecycle. The uses that have been discovered cover the phases of design, construction, and maintenance. Concluding the data analysis indicates that the mean scores fall within the average range. This shows that the Nigerian building construction industry is becoming more aware of the applications of Building Information Modeling (BIM).

The results of the data analysis show that the Nigerian building firms were more aware of BIM uses in the Design Stage with Cost Construction Planning having an MIS of 3.95, Construction Monitoring in the Construction stage having an MIS of 3.09, and Asset management with an MIS of 2.79 in the Maintenance /Operation Stage of projects. Thus, this supports the findings of previous studies; nevertheless, there was a small divergence in the order of the different uses, with the MIS being ranked higher than those noted in their investigation [45, 56]. The data indicates a rise in the degree of BIM use awareness, although the Maintenance Stage still has a severely low level of awareness. The findings further support the assertion that design professionals are the forefront users of BIM in the building industry [73].

Moreover, the relationship between BIM awareness levels across the building stages was investigated, the findings of the analysis indicate a highly significant and robust relationship between the level of awareness at the design stage and the construction stage ($r = 0.937$), the design and operation stage ($r = 0.925$), and the construction stage and the operation stage ($r = 0.967$). This result is contradictory to a study where it was only between the design stage and construction stage where the relationship was strong while there was a weak but significant relationship between the level of awareness at the design stage and operation/facility management stage and that of construction/building stage and operation/facility management stage was fair [74].

Level of usage of BIM across the building stages in the Nigerian building industry

The analysis of data in this present study shows that although BIM is being used across the building stages, its adoption is yet generally low. The adoption rate was analyzed to be 32%. This rate provided a negative indication of BIM adoption in Nigeria's building industry. According to the analysis of the study survey data, BIM is primarily used during the "Design" stage of building projects. Nonetheless, this study clearly shows that BIM is not frequently employed at the operation stage of built facilities in the study area, despite the huge advantages of BIM at the operational stage of buildings, as highlighted by a study [75].

The study went on to examine the potential impact of the firms' yearly turnover on BIM adoption. The study found a significant difference in BIM usage among respondents based on their firm's annual turnover ($F = 6.626$, $p < 0.05$). Based on this finding, it was concluded that annual firms' turnover influences the extent of BIM utilization in Nigeria's building industry. Firms with less than 1 million yearly turnover use less BIM than those with 101-250 million or more. This seemed to corroborate a study that stated that organizations approaches to new innovations depends so much on their size and the annual turnover [76]. Larger companies are known to devote more resources to research and development than SMEs with lower levels of innovation potential, and due to their larger resources, they are also known to embrace innovations more slowly [81]. SMEs frequently show reluctance to engage in innovative projects that take them beyond of their comfort zones due to the significant financial and risk involved [77]. Innovations that fit into the organization's current capabilities and can quickly benefit the business are quickly adopted by them [39]. However, Extensive research studies have found the adoption of BIM as a radical process and a huge transformation.

Barriers to BIM adoption in the Nigerian building industry

An examination of the literature showed some impediments to the adoption of BIM in nations around the world. This present study identified 39 barriers to the use of BIM in the Nigerian building industry. The 39 identified barriers to the adoption of BIM in the Nigerian building industry were checked against Kaiser-Meyer-Olkin (KMO) and Barlett’s test of specificity and then subjected to factor analysis. Therefore, the data were found to be good, with a Kaiser-Meyer-Olkin (KMO) value of 0.906, which is in line with the value of 0.6 as suggested by Kaiser (1974) and a Barlett's test specificity value of 0.000 (less than.05) with an approximate chi-square value of 1399.054 and df = 190. Principal component analysis (PCA) was used to do an initial non-rotated factor analysis and extract five significant components with eigenvalues greater than one to determine the number of factors to be extracted for the rotated factor analysis. The five main factors extracted are interpreted as: Human factors group; Management factors group; Technological factors group; Project factors group; and External factors group.

Furthermore, the results of this present study show that the percentage of explained variance by the extracted five factors that served as barriers to BIM adoption in the study area was 76.76%. The human factors group explained 21.50% of the barriers to BIM adoption in the study area, the Management factors group explained 19.88%, the Technological factors group explained 15.81%, the Project factors group explained 10.70%, and the External factors group explained 9.86%.

According to this study, the human factor group accounts for 21.50% of the total variance of barriers to BIM adoption in the Nigerian building industry. It is composed of seven main items, which are as follows Ignorant of BIM usefulness, interest, work motivation, personal competency, perceived ease of use, and experience and skills. With a mean score of 3.79, the survey respondents gave "Ignorant of BIM usefulness" top priority, indicating that it has the biggest impact on the participants' adoption of BIM. This finding is consistent with the findings of a few earlier research which suggested that users' acceptance of BIM software is contingent upon its perceived usefulness [78, 79, 80]. According to several research, ignorance of BIM usefulness is the main factor influencing behavioral intention to use BIM [81, 82, 83,]. Respondents' attitudes toward using BIM declined and their intention to adopt dramatically reduced when they lack the knowledge of its value [84]. Lack of experience and skills element is the second most critical barrier in the human factor category with a mean score of 3.67. A study provided support for this ranking by elucidating how BIM intentions to use were primarily impacted by insufficient experience and skills with new technology, followed by a lack of training and low self-efficacy [85]. This result, however, contradicts the finding of another study, which placed human resources' experience at number 41 out of 45 criteria. In this sense, an individual's intention to utilize BIM is typically unaffected by their experience and skills.

Additionally, the Management Factors Group accounted for 19.88% of the barriers to BIM adoption in the study area and financial resources rank highest in this group with a mean score of 3.69. This suggests that the significant financial cost of acquiring BIM software and the corresponding staff training that is necessary are regarded as a major obstacle to the adoption of BIM by Nigerian building industry firms. The initial outlay for putting BIM technology into practice is high. To support the collaborative nature of BIM, firms may need to make investments in hardware improvements, training, and organizational structure modifications in addition to software licenses. Many firms, particularly small and medium-sized businesses (SMEs), find these expenses to be unaffordable and are reluctant to abandon the more dependable and less costly CAD solutions.

The factor "Lack of awareness of BIM's full potential" ranks second in this category with a mean score of 3.65, indicating a considerable impact on the use of BIM in a project. A study added credence to this ranking by pointing out that, in addition to internal readiness and external influences, one of the three primary variables influencing the AEC industry's adoption of BIM is a lack of knowledge of the technology's full potential [86]. Moreover, the unavailability of BIM users was ranked second among the 11 management factors group with a mean score of 3.56, suggesting that organizations consider the availability of qualified workers with BIM tool proficiency when making their decision to utilize BIM software. This ranking is consistent with some earlier studies which demonstrated that the most important factor influencing BIM application was the unavailability of professionals with the necessary training to manage BIM tools [87, 88].

Furthermore, the technological factors group has 15.81% of the total variance of barriers to BIM adoption in the study area. The fact that "BIM tools installation requirements" scored highest among these factors indicates that it is a critical barrier to BIM adoption. This is because not all types of computer systems are suited for the installation of BIM-compliant programs, hence leading to discouragement of BIM adoption. The result of the analysis also found project scale as the number one barrier under the project factors group that hindered the adoption of BIM in the study area. This could be due to the majority of the projects being carried out by the sampled firms in the study area are residential buildings as they accounted for 21.7% and were perceived to be as too small. Contrarily to this finding, a study asserted that BIM is not exclusively reserved for large-scale projects but has equal and efficient applicability in both large and small projects. Even though the size does not matter, the important thing here is the improvement of collaboration, communication, process, workflow, quality of deliverables, eliminating or minimizing waste, decreasing the period, and reducing production and construction costs.

These findings confirm the existing literature. For instance, a study found that the lack of awareness and technical know-how of BIM among AEC firms is the reason for the industry's ignorance of the technology. Accessibility to BIM technology and framework was determined to have a substantial impact on BIM adoption [89](Osuji, Nkeleme, and Ezeokoli 2020). Furthermore, They also found that adopting BIM is hindered in the majority of underdeveloped countries by a lack of access to technology and structure. It was discovered that big upfront capital expenditures are required when using BIM for "first-timers," including hiring staff members and purchasing BIM computer hardware and software [90].

The results of this present study show that the overall top five ranked success factors of BIM adoption in building industry firms are: incorporation of BIM to the academic curriculum; improve BIM awareness and understanding; provision of training by employers; reduction in cost of implementing BIM; and developing BIM guidelines with their total mean score values of 4.64, 4.56, 4.49, 4.32, and 4.31 respectively. The results of this investigation support the body of current literature. For example, cooperation, training, and promotion were shown to be the best approaches for BIM implementation in Hong Kong [91]. According to a study, BIM should also be required for all contracts and procurement procedures, and a BIM council should be established [92].

From the result of this study, the main benefits of using BIM in the building industry are: minimizing errors and mistakes (RII=0.956), improving project quality (RII=0.962), and reducing rework in construction (RII=0.976). improving multi-party-communication-and collaboration (RII=0.947), improved project documentation (RII=0.944), improved clash detection (RII=0.953), shortened construction time (RII=0.948), improved efficiency and productivity (RII=0.939), decreased project costs (RII=0.933), and minimized disputes and conflicts (RII=0.932 While the least important benefits of BIM adoption based on this study are; facilitating asset and equipment maintenance and management (RII=0.867); increasing energy efficiency (RII=0.867); providing accurate and up-to-date information (RII=0.862); monitoring and tracking construction progress (RII=0.855); enhancing team-building abilities (RII=0.853); and creating space for more off-site materials/component prefabrication (RII=0.836).

The results of this investigation align with previously published documented literature, such as studies by [93, 94, 95, 96, 97, 98]. 'Rework' is one of the biggest issues facing the building sector.

Certain problems with poor quality, increased waste, disagreements, cost overruns, delays, and lost revenues have been attributed to rework. On building projects, BIM is found to minimize this issue, as buttressed by a study [99].

4.4 Validation of Conceptual Framework of the Study

The conceptual framework presented in Chapter Two of this thesis shows the five key components of the research that were investigated, and how they relate with one another (see Figure 2.11). These five components formed the background for data collection and analysis. …nceptual framework of this study was developed prior to the survey. After …a analysis it was important to validate the frame work in the light of the …earch. Using the result of this research, a validated conceptual framework …lding information modelling are presented as shown in Figure 4.7.

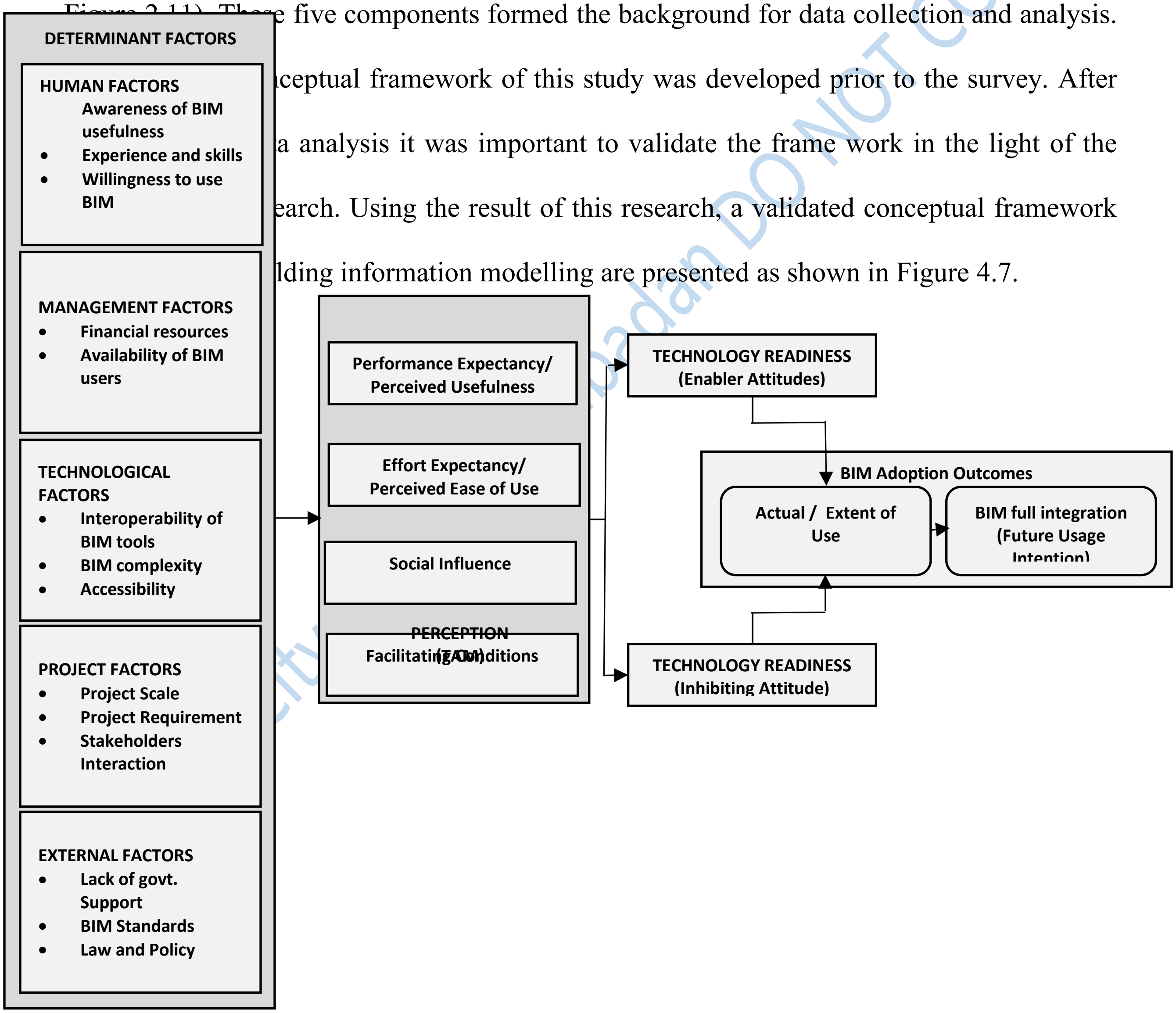

Figure 4.7 Validation of Conceptual Framework
Source: Researcher (2024)

Endnotes

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Chapter Five

Conclusion

5.1 Summary of Findings

This study revealed the results of a survey designed to determine the current state of BIM adoption in the Nigerian building industry with the view of fine-tuning communication and collaboration among the stakeholders. The study adopted a quantitative research approach by eliciting primary data through a questionnaire survey which was administered to 734 building industry firms in southwestern Nigeria, of which 656 were returned and considered valid for further analysis. Both descriptive and inferential statistics are used for the analysis. These were achieved using the Statistical Package for Social Sciences (SPSS) version 20.

The analysis of the demographic characteristics showed that the respondents are highly experienced and have played significant roles in their firms. 43.8% had worked in the building industry for more than 20 years, 18.8% had experience between 11 and 20 years, and 37.5% had experience of at least 10 years or less. Additionally, the results indicated that

26.4% of respondents work in architectural or design offices, 24.7% in structural engineering firms, 27.1% in building consulting and contracting firms, and 21.8 % in quantity surveying firms. Most respondents' project specializations are residential and all building types, accounting for 21.7 and 67.5% of responses, respectively. It was also discovered that the majority of the examined companies (51.1%) were headquartered in Lagos. This may be due to Lagos, the most populated and commercialized city in Nigeria, offering a ready market for services rendered by firms in the building industry.

The awareness and use of BIM-compliant software in the Nigerian building industry were examined. The study revealed that most of the respondents' firms were aware of software packages that comply with BIM, but the level of usage was not commensurate with the level of awareness. It was found that AutoCAD, Revit Architecture, and Sketch-Up were the most often utilized software products among the Nigerian building industry firms. Moreover, the awareness of BIM uses across the building stages was also assessed, it was discovered that the BIM uses awareness level is only high at the design stage of a building life cycle while it is average at the construction stage and extremely low at facility management stages. The majority of building industry firms are mostly unaware of how BIM may be used at the facility management stage for record modeling, sequencing, asset management, fabrication, maintenance schedules, and building system analysis. However, there is a very strong and significant relationship between the level of awareness at the design stage and the construction stage ($r = 0.937$), the design and operation stage ($r = 0.925$), as well as the construction and the operation stage ($r = 0.967$). The level of BIM awareness among Architects and Engineers is a bit higher than that of Builders and Quantity Surveyors.

However, there was no significant difference among the different professional firms (0.05 level of significance) in BIM awareness

The level of BIM usage across the building stages was also evaluated. The level of BIM usage in the Nigerian building industry is low (32%). Moreover, regarding the extent of use of BIM software packages in the various stages of work in the building industry, the study found that although it appears that the respondents use BIM across the various stages of project execution, there is a predominant use of BIM at the design stage (69%). This is followed by the use of BIM at the construction stage (19%) as well as the maintenance/operation stage (12%). BIM is rarely used in the operation stage of constructed facilities in the study area. Furthermore, the annual turnover of the firms influences the level of usage of BIM among the firms in the study area. Those firms with <1M annual turnover have low levels of BIM usage compared to the firms with an annual turnover of 101 – 250M and > 250M which have high levels of BIM usage.

Barriers to the adoption of BIM in the Nigerian building industry were of five categories as extracted using factor analysis. These are the human factors group, the management factors group, the technological factors group, the project factors group, and the external factors group. The analysis demonstrated that factor 1 explained 21.50% of the barriers that influence firms' BIM adoption in the Nigerian building sector, whereas factors 2, 3, 4, and 5 accounted for 19.88%, 15.81%, 10.70%, and 9.86%, respectively. The most influential barrier was perceived usefulness in the human factors group (mean = 3.79), followed by financial resources in the management factors group (mean = 3.69), speed of BIM tools in the technological factors group (mean = 3.75), project scale in the project factors group (mean = 3.58), and government support in the external factors group (mean = 3.72).

All the ten identified success factors of BIM adoption in the building industry firms were considered critical factors for BIM adoption in the study area as their mean values range from 3.97 to 4.64. In addition, the overall top five ranked critical factors of BIM adoption in the study area are the incorporation of BIM into the academic curriculum; improve BIM awareness and understanding; provision of training by employers; reduction in cost of implementing BIM; and developing BIM guidelines with their total mean score values of 4.64, 4.56, 4.49, 4.32, and 4.31 respectively. Except for one (out of ten) identified success factors of BIM adoption, there is no statistically significant difference in the perspectives of the four respondents' categories (firms).

The six main benefits of adopting BIM in the building industry among the firms in the study area are: it reduces errors and mistakes (RII=0.956), improves project quality (RII=0.962), reduces construction rework (RII=0.976), improves multi-party communication and collaboration (RII=0.947), improved project documentation (RII=0.944), and improved clash detection (RII=0.953). The least important benefits of BIM adoption are: creating space for more off-site materials/component prefabrication (RII=0.836), information access is quick and dependable (RII=0.823), enhancing facility operation and maintenance decision-making (RII=0.820), facilitates more precise and quick project cost and time estimation (RII=0.818), and permits flexible and sustainable design (RII=0.802).

5.2 Conclusion

This study investigated the current state of BIM in the Nigerian building industry to fine-tune communication and collaboration among the stakeholders. BIM has much potential to improve the effectiveness of construction works concerning design, construction, and maintenance. Even though various factors are hindering the progress of BIM adoption among

Nigerian building industry firms, based on the results, the following conclusions can be made. Firstly, there is a high level of awareness of BIM-compliant software among the firms in the study area. However, the software's usage level was not commensurate with the level of awareness. The most commonly used BIM-compliant software packages are Autodesk Quantity Takeoff, Revit Architecture, and SketchUp.

Secondly, only during the design phase of a building's life cycle is the level of BIM usage awareness high; during the construction phase, it is average, while during the facility management phase, it is very low. Most firms in the study area don't know how BIM may be used for record modeling, sequencing, asset management, fabrication, maintenance scheduling, and building system analysis at the facility management stage. Furthermore, the level of BIM awareness among Architects and Engineers is a bit higher than that of Builders and Quantity Surveyors. However, the difference is not statistically significant ($F = 1.732$, $P>0.05$).

Thirdly, the level of BIM usage in the Nigerian building industry is low. While the respondents seemed to use BIM at every level of the project execution process, the design stage is when BIM is most frequently used (69%). The use of BIM during the construction stage (19%) and the maintenance/operation stage (12%), respectively, come next. In the study area, BIM is hardly ever employed during the operation phase of built facilities. Additionally, the amount of BIM usage among the firms in the study area is influenced by the yearly turnover of the firms.

Furthermore, perceived usefulness was the most influential barrier, followed by financial resources, BIM tool speed, project scale, and government support. In addition, the overall top five ranked critical success factors of BIM adoption in building industry firms are the incorporation of BIM into the academic curriculum; improve BIM awareness and understanding; provision of training by employers; reduction in the cost of implementing BIM; and developing BIM guidelines with their total mean score values of 4.64, 4.56, 4.49, 4.32, and 4.31 respectively. In addition, except for one (out of 10) identified success factor of BIM adoption; there is no statistically significant difference in the perceptions of the four respondents' groups (firms).

Finally, the main benefits of using BIM in the building industry in the study are: minimizing errors and mistakes, improving project quality, reducing rework in construction, improving multi-party communication and collaboration, improving project documentation, improving clash detection, shortening construction time, improving efficiency and productivity, decreased project costs, and minimized disputes and conflicts. The least important benefits of BIM adoption based on this study are; permitting flexible and sustainable design, facilitating more precise and quick project cost and time estimation, enhancing facility operation and maintenance decision-making, information access is quick and dependable, and creating space for more off-site materials/component prefabrication. Regardless of how these are arranged to one another, these criteria ultimately continue to demonstrate the crucial role that BIM adoption plays in building projects.

5.3 Recommendations

Based on the findings and conclusion of the study, the following recommendations were made:

i. Professional bodies should continue organizing BIM–related workshops and seminars for their members to further acquire appropriate BIM skills and technical know-how

ii. The cost of BIM software and training of staff should be subsidized by the various professional building industry firms, government, and other approved authorities.

iii. The BIM concept should be incorporated into academic curricula of architecture, engineering, and construction-related disciplines in higher education

iv. Stakeholders of the building industry should be open to adopting new construction technologies that will increase the productivity of construction work.

v. The government should invest heavily in BIM-related research to enhance the body of knowledge on BIM in Nigeria and develop a suitable framework or guidelines for BIM implementation

vi. Policy Development: The Government should enact policies that will encourage the implementation of BIM in Nigeria.

5.4 Contribution to Knowledge

The study contributed to the existing body of scientific knowledge in the area of building information modeling by:

i. Providing regional and contextual insights specific to Southwest Nigeria, highlighting regional challenges and opportunities in the adoption of BIM. This knowledge can inform stakeholders about local barriers such as infrastructural deficits and the need for tailored training programs.

ii. Pinpointing factors that could be strengthened and improved to maximize the benefits of BIM in the building procurement process and reach a critical mass uptake of BIM in Nigeria's building industry.

iii. Providing policymakers with information on awareness and adoption of BIM in the Nigerian building industry. This includes identifying adoption drivers and barriers, allowing for the development and implementation of policies to promote easy adoption of BIM. Adopting building information modeling can boost the building industry's economic worth, promoting growth and benefiting the country.

iv. Developing a framework for examining the adoption of BIM in the Nigerian building industry. This framework can be used as a basis for research into other innovations outside building information modeling, whether they are in the building industry or not. It can also be replicated in other geo-political zones to investigate similar contexts, thereby validating the framework as appropriate for the studies into the adoption of BIM.

5.5 Suggested Areas for Further Research

The following areas have been suggested for further research given the gap identified from this study and previous studies:

i. Other studies should investigate the impact of the adoption of building information modeling on the quality of building projects in the Nigerian building industry.

ii. This study used a cross-sectional survey with a questionnaire as the primary data collection method. Questionnaires are limited in their ability to generate qualitative insights due to their focus on quantitative-only nature. Future studies should use longitudinal survey research designs, including questionnaires and interviews, to acquire data from the target population.

iii. More evidence-based studies are needed to prove BIM's effectiveness in improving collaboration and communication throughout building project delivery. Case studies are required to precisely measure BIM benefits on the building projects selected for study. This will further validate the findings of the current research.

iv. Similar study could be carried out on building information modeling in the other geo-political zone in Nigeria and then now do comparative studies among them.

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Appendix 1

The Department Of Architecture,

Faculty of Environmental Design and Management,

Lead City University,

Ibadan.

Questionnaire on **" Assessing Building Information Modeling Adoption in the Nigerian Building Industry in Southwest Nigeria"**

Dear Respondent, I wish to research" Adoption of *Building Information Modelling Adoption in the Building Industry- Southwest Nigeria* ''. In the following survey, please respond only to those questions by ticking the appropriate blanks. It would be appreciated if you could kindly assist in completing the questionnaire with utmost sincerity. I assure you that your response shall be used strictly for research purposes and be treated confidentially.

Thanks in advance for your cooperation.

Alaje A. Akinola.

Section A: Demographic Characteristics

Instruction: Indicate your opinion by ticking **(** √ **)** inside the bracket

1. What type of firm do you work for? Architectural Firm **( )** Building Firm **( )** Engineering Firm **( )** Quantity Surveying Firm **( )**

2. Firm Location: Ado-Ekiti (Ekiti state) ( ) Ikeja (Lagos state) ( ) Abeokuta (Ogun state) ( ) Akure (Ondo state) ( ) Osogbo (Osun state) ( ) Ibadan(Oyo state) ( )

3. What is the size of your firm (by staff)? < 10 staff (micro firm) ( ) 11 – 50 staff (small firm) ( ) 51 – 250 staff (medium size firm) ( ) > 250 staff (large firm) ( )

4. How many years has the firm been in operation (Age of the firm)? < 5 years ( ) 6 - 10 years ( ) 11 - 20 years ( ) 21 - 30 years ( ) > 30 years ( )

5. What project area does your firm specialize in? Mostly Commercial ( ) Mostly Residential ( ) Mostly Institutional ( ) Mostly Industrial ( ) All building types ( )

6. What range is your firm annual turnover? < 1M ( ) 1 – 10M ( ) 11 – 50M ( ) 51 – 100M ( ) 101 – 250M ( ) >250M ( )

7. What is the range of your working experience in this field? 1 – 5yrs (   ) 6 – 10yrs (   ) 11 – 15yrs (   ) 16 – 20yrs (   ) 21 – 25ys (   ) above 25yrs

B: BIM Compliant Softwares Awareness

8. Which of the following BIM Software applications are you aware of? **(Note: you can tick more than one option)**

Tekla Structures	( )	PowerCivil	( )
Archicad	( )	Digital Project	( )
ArchiFM	( )	Navisworks Manage	( )
Green Building Studio	( )	Autodesk Quantity Takeoff	( )
Masterbill	( )	VICO Software	( )
Revit Architecture	( )	Bentley BIM Suite	( )
Sketchup	( )	QS CAD	( )

C: BIM Software Applications Usage

9. Which of the following BIM software applications do you use? **(Note: you can tick more than one option)**

Tekla Structures	( )	PowerCivil	( )
Archicad	( )	Digital Project	( )

ArchiFM	( )	Navisworks Manage	( )
Green Building Studio	( )	Autodesk Quantity Takeoff	( )
Masterbill	( )	VICO Software	( )
Revit Architecture	( )	Bentley BIM Suite	( )
Sketchup	( )	QS CAD	( )

D: BIM Usage Across the Building Stages (Awareness Level)

10. Have your firm heard or is aware of BIM (uses)? Yes ( ) Not Sure ( ) Not ( )

11. Are your firm aware that BIM could be used to achieve the following at the different building stages? Kindly rate your extent of awareness based on the following indices (where 1 = Not Aware; 2 = Less Aware; 3 = Not Sure; 4 = Aware; 5 = Very Aware)

a. Design Stage

s/n	Achievements	1	2	3	4	5
i.	Cost Estimation					
ii.	Construction Planning					
iii.	Coordination					
iv.	Prefabrication					
v.	Visualization					
vi.	Constructability Analysis					
vii.	For Sequencing					

b. Construction Stage

s/n	BIM Usage	1	2	3	4	5

i.	Construction Monitoring					
ii.	Clash Detection					
iii	Maintenance Scheduling					
iv.	Fabrication					

c. Maintenance/Operation Stage

s/n	BIM Usage	1	2	3	4	5
i	Asset Management					
ii	Building System Analysis					
iii	Record Modelling					

E: Level of BIM Usage at different building stages

12. At what building stage do you use BIM applications? **(Note: you can tick more than one option);** Design stage ( ) Construction stage ( ) Operation/Maintenance stage ( )
13. How frequently do you use BIM? Kindly rate your extent of usage based on the following indices:

    Never ( ) Rarely ( ) Sometimes ( ) Often ( ) Always ( )
14. Which of the following building activities do your firm engage BIM to achieve? **(Note: you can tick more than one option)**

S/N	Building Activities	**Tick (√)**
i.	Construction Planning	
ii.	Visualization	
iii.	3D Coordination	
iv.	Cost Estimation	
v.	Prefabrication	
vi.	Constructability Analysis	
vii.	Sequencing	
viii.	Construction Monitoring	
ix.	Clash Detection	
x.	Maintenance Scheduling	
xi.	Fabrication	
xii.	Asset Management	
xiii.	Building System Analysis	
xiv.	Record Modelling	

F: BIM Benefits

15. What premium would you place on BIM benefits? Kindly rate your level of importance based on the following indices (where 1 = Not important; 2 = Somewhat important; 3 = Neutral; 4 = Important; 5 = Very important)

s/n	BIM Benefits	1	2	3	4	5

i.	Improve project design					
ii.	better clash detection					
iii.	better coordination					
iv.	Reduce Rework in Construction					
v.	better synchronization					
vi.	better projects sequencing					
vii.	give room for more off-site materials/components prefabrication					
viii.	enable visualization of the built environment					
ix.	improves health and safety					
x.	Allow for flexibility and sustainable design					
xi.	facilitate equipment and asset maintenance and management					
xii.	Provides a digital model that can be utilized throughout the building life cycle.					
xiii.	more accurate and speedy estimation of project cost and time					
xiv.	improvement in energy efficiency					
xv.	improve resources planning and sequencing					
xvi.	effective management of project resources procurement and storage					
xvii.	allows for effective and efficient utilization of site					
xviii.	Improves efficiency and productivity					
xix.	Improves decision making at the operation and maintenance of a facility.					
xx.	Access to information is fast and reliable					

xxi.	Provision of accurate and updated information					
xxii.	Improving team building skills					
xxiii.	monitor and track progress during construction					
xxiv.	Improve services delivery					
xxv.	Project cost reduction					
xxvi.	Reduced Construction Time					
xxvii.	Improve project Quality					
xxviii.	Improve project documentation					
xxix.	improve multi-party communication and collaboration					
xxx.	Minimize Errors and mistakes					
xxxi.	Constructability improvement					
xxxii.	Minimizes disputes and conflicts					

G: Factors that Influence BIM Adoption

16. What is your stand on the factors below that affect the adoption of BIM in your professional practice? (where 1 = Strongly Disagree; 2 = Disagree; 3 = Not sure; 4 = Agree; 5 = Strongly agree)

	Limiting factors/barriers	1	2	3	4	5
1	Unwillingness to use BIM					
2	Lack of Experience and Skills					
3	Negative Perception of Ease of Use					
4	Personal Incompetency					
5	Absence of Work Motivation					
6	Lack of Interest					
7	Ignorant of BIM usefulness					
8	Unavailability of technical infrastructure					
9	Financial resources					
10	Unavailability of BIM users					
11	Perceived risks					
12	Organizational readiness					
13	Organization's culture					
14	Organization's capacity					
15	Organization's policies					

16	Lack of Manager's support					
17	Lack of Capacity to use information technology					
18	Ignorance of benefits of BIM for organization					
19	Technology Quality					
20	Speed of BIM tools					
21	BIM complexity					
22	Trialability					
23	Speed of BIM tools					
24	IT support					
25	Result demonstrability					
26	Accessibility					
27	Functionality					
28	Feasibility using BIM					
29	Procurement methods					
30	Stakeholders interaction					
31	Project scale					

32	Stakeholders' awareness					
33	Project requirements					
34	Project complexity					
35	BIM standards					
	BIM instructions					
36	BIM providers					
37	Competition levels					
38	Laws and policies					
39	Lack of Government support					

	Critical Success Factors (CSFs) for BIM Adoption	1	2	3	4	5
40	Incorporation of BIM into academic curriculum					
41	Improve BIM awareness and understanding					
42	Outsourcing BIM experts					
43	Provision of training by employers					
44	Government Legislation supporting the use of BIM					
45	Developing BIM guidelines					
46	Reduction in cost of implementing BIM					
47	Setting up BIM council					

48	Compulsory use of BIM for all procurement and contract					
49	Provision of appropriate technology and infrastructure					

Appendix II

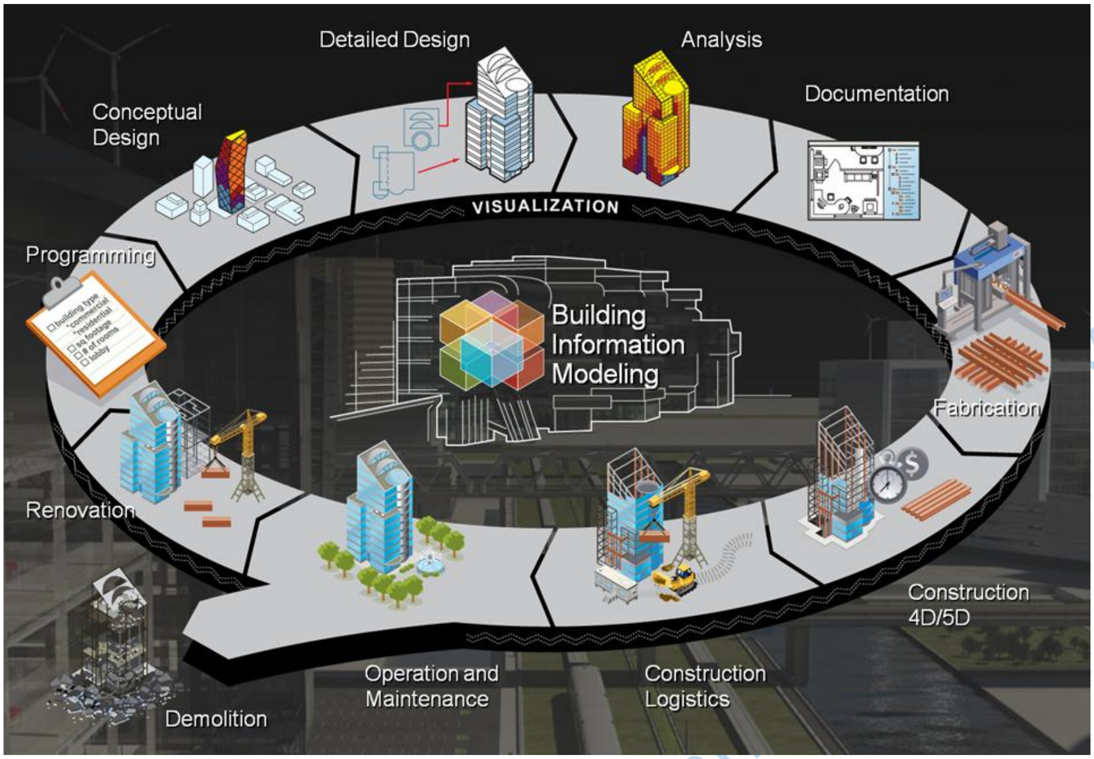

Figure1: BIM Network

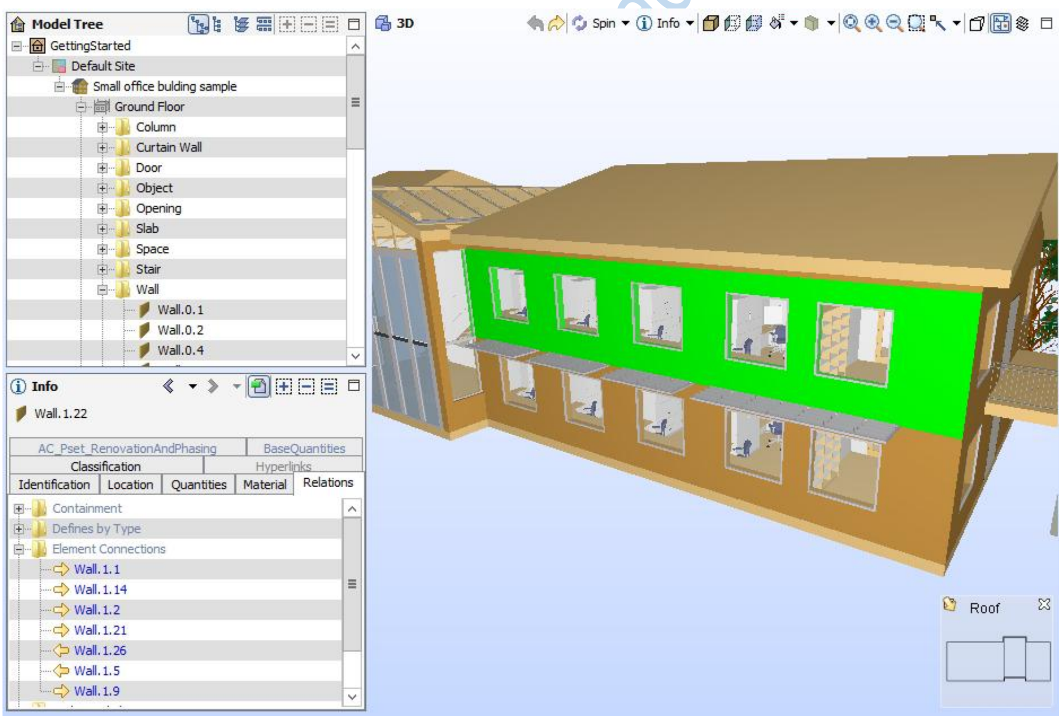

Figure 2: BIM Model

APPENDIX III

List of Registered Firms in Lagos

1. List of Architectural firms

S/N	NAMES OF FIRMS
1.	ABA ARKY AND ASSOCIATES
2.	A.B. RUCH LIMITED
3.	ABORRH ARCHITECTS
4.	A.D. CONSULTING LIMITED
5.	ADENIYI COKER CONSULTANTS LIMITED
6.	ADE-OJURI AND PARTNERS
7.	ADEYINKA CONSULT
8.	ADMAG CONSULT
9.	AEK DESIGN SERVICES
10.	AEQUITAS KONSULT LIMITED
11.	AGBESUA AND ASSOCIATES
12.	AGRAM NIGERIA LIMITED
13.	AIM INTEGRATED ARCHITECTS AND CONSULTANTS LIMITED
14.	AINA + ASSOCIATES DESIGNS LTD
15.	AKIN OLUSOLA AND ASSOCIATES
16.	AKINRINSOLA PARTNERS
17.	ADOLF PROJECT DEVELOPMENT LIMITED
18.	AKOGWU PRIME CONCEPT ASSOCIATE
19.	ALAT SERVICES COMPANY
20.	ALEK ASSOCIATES
21.	ALEX CARPE CONSULTING
22.	ALLISON-ADE NIGERIA LIMITED
23.	AMBA ASSOCIATES
24.	A.M. ANFANG CONSULTANTS
25.	AMA DESIGNS
26.	AMARCH CONSULTANTS
27.	AMPUCA AND PARTNERSHIP LTD
28.	ANETOR + ASSOCIATES LIMITED
29.	ANOMBEM MOKWUNYE TWIGG BROWN
30.	ANTZ ARCHITECTS
31.	API CONSULTANTS LIMITED
32.	ARC DESIGN PRACTICE
33.	ARCHCADRE
34.	ARCHI-HIVES
35.	ARCHIKRAFT ASSOCIATES NIG. LTD.
36.	ARCHI-TEXT DESIGNS ASSOCIATES
37.	ARCHITRADE KONCEPT
38.	ARCHI-VIRON ASSOCIATES
39.	ARCHI-AFFAIRS LIMITED
40.	ARCHIFAD CONSULTANT
41.	ARCHIMEDIA CONSULTS
42.	ARCHIPLEX CONSULT
43.	ARCHISCOPES ASSOCIATES
44.	ARCHITECTURAL SERVICES CONSULTANTS
45.	ARCHWORKS ASSOCIATES
46.	ARCHMODULE NIG. COMPANY
47.	ARCHPLENG CONSULTANTS

48. ARCHITECTS PARTNERSHIP
49. ARC-QQUA ASSOCIATES
50. ARTHUR ORONSAYE AND ASSOCIATES
51. ATINUKE EJIWUMI AND PARTNERS
52. ATO ARCHITECTS LIMITED
53. ATOPIC LIMITED
54. AZDEC A.S. DESIGN CONSULTANTS
55. ARCHI-PLANCON ASSOCIATES
56. ARCHI-KRAFT CONSULT
57. ARCH HEIGHT DESIGN THEATRE
58. ARCHITECTURAL SERVICES CONSULTANTS
59. BEN-EBOH ASSOCIATE
60. BENELUX PROJECTS LIMITED
61. BIJAURCH ASSOCIATES
62. BIOR-JAG AND ASSOCIATES
63. BIOS LIMITED
64. B AND L ARCHITECTS
65. BISI DIVERSIFIED NIGERIA LIMITED
66. KOLEOSHO AND PARTNERS
67. BRECON ARCHITECTS
68. BUILDERS POINTS AND ASSOCIATES
69. BUILDING DESIGN ASSOCIATES
70. B.U.D CONSULTANTS
71. B-WAKS CONSULTANTS
72. BRAIN GRAN DESIGN PRACTICE
73. CASABUILD ASSOCIATES LIMITED
74. CDS GLOBAL LIMITED
75. CDC PARTNERSHIP
76. CEPKONCEPT
77. CONTEMPORARY ARCHITECTURAL LIMITED
78. COSMO-URBAN PROJECTS LIMITED
79. CHRYS CONCEPTS
80. COMPOSITE ARCHITECTS LIMITED
81. COMPREHENSIVE DESIGN ASSOCIATES
82. CONSTRAAD NIG. LTD
83. CONTEMPORARY DESIGN ASSOCIATES
84. CONSULTANTS COLLABORATIVE PARTNERSHIP
85. CRESCENT KONSULT
86. CROWN ARCHITECTS
87. CRUSCIBLES DESIGN AND BUILD NIG. LTD
88. DAA ARCHITECTS LIMITED
89. DAD KONCEPTS AND ASSOCIATES
90. DANCAD CONSULT
91. DARCHIWORKGROUP
92. DASA ARCHITECTS LIMITED
93. DELANO ARCHITECTS
94. DELTA DESIGN CONSULTANTS
95. DESIGN AID CONSORTIUM
96. DESIGN ALLIANCE

97. DESIGN GROUP NIGERIA LIMITED
98. DESIGN BASICS PARTNERSHIP
99. DESIGNFLAIR LIMITED
100. DESIGN LINES CONSULTANTS
101. DESIGN MECHANICS LIMITED
102. DESIGN UNION CONSULTING LIMITED
103. DESIGN VIEW CONTEMPORARY CONCEPT LTD
104. DEZARCH ASSOCIATES
105. DIOKPO AND T.A.M.
106. DISTINKT NIGERIA LTD
107. DKR ASSOCIATES LTD
108. DOA ASSOCIATES
109. DOLAPO BELLO CONSULTING ARCHITECTS LIMITED
110. DOM-SERINA NIGERIA LTD
111. DOX ASSOCIATES
112. DW CONSULTANTS
113. EARTHSCAPE CONCEPTS
114. EDEN GROUP OF COMPANIES
115. ECAD ARCHITECTS LIMITED
116. ECHO-MOLD COLLABORATIVE PARTNERS
117. ECK CONSULTANTS
118. EDORBI ASSOCIATES
119. ELASTRA NIGERIA LIMITED
120. EL-SHADDAI AND ASSOCIATE
121. ELSY ARCHITECTS LIMITED
122. ENVOYHYGIENIX
123. EMEKA OLISA EJIKEME AND ASSOCIATES
124. ENI-TAN AND COMPANY
125. FABIAN ODUDU ASSOCIATES
126. FARCON CONSULT
127. FMA ARCHITECTS LIMITED
128. FOEIRON INTEGRATED CONSULTANTS
129. FOLA ALADE ASSOCIATES
130. FOLABI AJIMOTI ARCHITECTS
131. FORM-ANNEX ASSOCIATES
132. FORM AND FUNCTION ASSOCIATES
133. FORM MASTER AND ASSOCIATES LIMITED
134. FORM SMITHS AND PARTNERS
135. FORMWORK ARCHITECTS LIMITED
136. FORM SCAPES LIMITED
137. FOUNDAMENTUM LIMITED
138. FREEBOARD ASSOCIATES
139. FUTURE SCAPE CONSULTANTS
140. GALEX DESIGN ASSOCIATES
141. GIFT-ARC CONSULTANTS
142. GLOBAL JULAID NIG. LTD
143. GLOBWOCS CO. LIMITED
144. GLOWING OAK COMPANY LIMITED
145. GODWIN HOPWOOD KUYE

146. GOLDEN PYRAMIDS SOLUTION LTD
147. GOTHIC-LEN CONSORTIUM
148. GRIDS ASSOCIATES
149. GROUP BAJO ASSOCIATES
150. GPS CONSULTS
151. HARRIS AIB ASSOCIATES
152. HOUSETOP ARCHITECTS
153. HOUSESMITHS LIMITED
154. HOLDMAN AND DOT NIGERIA LTD.
155. HOME AGENDA LIMITED
156. HOME WORK DESIGNS AND CONSULTANTS LIMITED
157. HUPLAN DESIGN CONSULTS

2. List of Engineering Firms

1. HBRID TECHNOLOGIES (HYTECH) LIMITED
2. INDEX ASSETS AND CONSULTING LIMITED
3. IEC ENGINEES LIMITED
4. I-DYNAMO ASSOCIATES
5. INNOVATE CONCEPTS LIMITED
6. INNOVATIVE DESIGN ASSOCIATES
7. INTEGRATED CONSULTANTS ENGINEERS
8. INTER DESIGNS PARTNERSHIP
9. INTER-ARC INITIATIVE
10. INTERLINKS TECHNOCRATS TEAM LIMITED
11. INTERSTATE ENGINEERS LIMITED
12. INTERMOL CONSULT LTD
13. INTRABETHEL DESIGNS LIMITED
14. INTRA DESIGN SERVICES NIGERIA
15. JAMES CUBITT ENGINEERS
16. JEB AND ASSOCIATES NIGERIA ENTERPRISES
17. JOINT CONSULT LTD
18. JO-REHOBOTH ASSOCIATES
19. KGB COLE PROJECTS LIMITED
20. KLIF CONSULTANTS
21. KONIN NIGERIA LIMITED
22. KELIYKE ASSOCIATES
23. KELNIC ASSOCIATES
24. KENNING HOMES LIMITED
25. KENPLANS CONSULTANTS
26. KONSTANCE CONSULT INTEGRATED SERVICES LIMITED
27. KONTECTURAL DESIGN AND ASSOCIATES
28. LAAD ASSOCIATES
29. LANDMARK ENGINEERS
30. LAVANTE GARAGE CONSULT
31. LAOYE DESIGN COMPANY
32. LEKAN ADAMS AND ASSOCIATES
33. LEKAN ADEGBITE ASSOCIATES

34. LEKAN LAWAL AND ASSOCIATES
35. LEKE ODUWAYE ASSOCIATES
36. LIEGE CONSULTANTS
37. LINESMITHS DESIGN ASSOCIATES
38. LINE 2 SPACE ENGINEERS LIMITED
39. MAJOROH PARTNERSHIP
40. MARIANO CONSULT NIGERIA LIMITED
41. MATRIX CONSULT
42. M.B.O ADEGBITE ASSOCIATES LTD
43. MANDC.D.S CONSULTS
44. MACROPLAN II AND ENGINEERS NIG.LTD.
45. METROPOLITAN STUDIOS
46. MICHE NIGERIA LIMITED
47. MILA ASSOCIATES
48. MINDSEYE ASSOCIATES LIMITED
49. MOEZ'ART
50. MORPHOSIS INC. LIMITED
51. MULTIXEPT ASSOCIATES LTD
52. NEW METHODS DESIGN ASSOCIATES
53. NIGER CONSULTANTS
54. NIYI BAKARE ASSOCIATES
55. NOARK CONSULT
56. NEW ORDER PARTNERSHIP
57. ODELEYE ASSOCIATES
58. ODELEYE INTERNATIONAL ASSOCIATES
59. OAC ENGINEERS
60. OGOLI NIGERIA LIMITED
61. OKUNLOLA ASSOCIATES
62. OLADELE OLUWAMOTEMI AND ASSOCIATES
63. OLAJIDE ADEBANJO ASSOCIATES
64. OLAWUNMI AGBAJE ASSOCIATES
65. OLUSEGUN KUTI DESIGNS
66. OMNI ENVIRONMENTAL SERVICES
67. OMNIARCH NIGERIA
68. OMUABUILD AND COMPANY
69. OPTIMUM CONCEPTS
70. PAUD ASSOCIATES
71. PAUL UZOR ASSOCIATES
72. PACKAGE DESIGN CONSULTANTS
73. PALDOATED ENGINEERING SERVICES LIMITED
74. PARADIGMSHIFT DESIGN LIMITED
75. PIEARCH LIMITED
76. PENTAGON CONSULTANTS
77. PHARCEPT CONSTRUCTION
78. PLARC CONSULTANTS
79. PLATFORM CONCEPT LIMITED
80. PLANNET LIMITED
81. PLURAL CONCEPTS CONSULTANTS NIGERIA
82. PM+CDC ASSOCIATES

83. PODEX ASSOCIATES LIMITED
84. POINT SCAPE
85. POLYGON CONSULTANTS
86. POPHAM WALTER ODUSOTE LTD
87. PRIMAL DESIGN CONSULTANTS
88. PRIMAVIS GLOBAL SERVICES
89. PROJECT DEVELOPMENT TEAM LTD
90. PROLINES DESIGNS CONSULT
91. PROLINKS ASSOCIATES
92. PROXIMAL HEIGHTS
93. PYRAMIDS
94. Q.A. ENGINEERS
95. Q-BAYS CONSORTIUM
96. RENX WORKS
97. RICH-CONSULT ASSOCIATES
98. RONALD WARD AND ASSOCIATES
99. ROYE IBRU ASSOCIATES
100. SCHEMATICS DEVELOPMENT GROUP
101. SCENIC VISIONS LIMITED
102. SEKDAN AND ASSOCIATES LIMITED
103. SHALOM EN-CONSULT INTERNATIONAL LIMITED
104. SHARON ROSE DESIGN LIMITED
105. SHELTER CONSULT
106. SHELTER SERVICES
107. SHOLMUD VENTURES LIMITED
108. SITES AND E LIMITED
109. SLICK DESIGN KONSULT
110. SOLIDGOLD LIMITED
111. SPACE CONCEPTS LIMITED
112. SPACECRAFT LIMITED
113. SPACEWEB CONSULTING LIMITED
114. SPATIAL DESIGN CONSULTS LTD
115. SPECTROPLAN KONSULT LIMITED
116. SPACE AND PLACE
117. ST. NICHOLAS AND ASSOCIATES
118. STARZS CONSULTANTS

3. List of Quantity Surveying Firms

S/N NAMES OF FIRMS

1. A-QS ASSOCIATES
2. ACE(QS) CONSULTANTS
3. ACO AND PARTNERS
4. ADERONKE OYELAMI ASSOCIATES
5. ADESANYA AND PARTNERS
6. AIM CONSULTANTS (NIG) LTD
7. AKINWONMI AND ASSOCIATES CONSULTANTS
8. ALLIED QUANTITY SURVEYINGS
9. AMAG CONSULTING ASSOCIATES

10. AMOLAD CONSULTANTS
11. ARIBISALA ASSOCIATES
12. ASABI AND PARTNERS
13. AUSTIN ONARO AND ASSOCIATES
14. BEC CONSULTANTS NIGERIA
15. BAM ASSOCIATES
16. BEEB ASSOCIATES
17. BILLING COST ASSOCIATES
18. BISI ADEOYE AND ASSOCIATES
19. BQC CONSULTANTS LTD
20. BROAD COST CONSULT
21. BST CONSULTANT
22. CEE BEE PARTNERSHIP
23. CHAVAN ASSOCIATES
24. CHIDEBELU PARTNERSHIP
25. CLIFFON ASSOCIATES
26. COGN ASSOCIATES
27. COLLINS ASSOCIATES
28. CONCOST PARTNERSHIP
29. CONSOL ASSOCIATES
30. CONSTRUCTION ECONOMIST PARTNERSHIP
31. COST AND CONTRACT CONSULTANTS
32. COST BASE ASSOCIATES
33. COST DIMENSION ASSOCIATES
34. COST MATRIX CONSULT
35. COST MODEL ASSOCIATES
36. COST VALUE TIME CONSULTANTS
37. COSTCARE PARTNERSHIP
38. COSTEC CONSULTANTS
39. COSTEL ASSOCIATES
40. CSOTEL QUANTITY SURVEYING
41. COST-LINK ASSOCIATES
42. COSTWORTH ASSOCIATES
43. CYVA PARTNERSHIP
44. DELSTEIN CONSULTANTS
45. DESAN PARTNERSHIP
46. DESIGN QUANTS ASSOCIATES
47. DONS AND ASSOCIATES
48. DURO OLAMIDE ASSOCIATES
49. DWAB COST PRUDENCY COMPANY
50. EFA ASSOCIATES
51. EJIK DONENE AND PARTNERS
52. EKEOBA AND EMIOWELE PARTNERSHIP
53. EMEKA OSEMENAN AND ASSOCIATES
54. EMMABOS ASSOCIATES
55. EMMANOLU ASSOCIATES
56. FEMI POPOOLA AND PARTNERS
57. FO-AB PARTNERSHIP
58. FOBAT ASSOCIATES

59. FOLMAK PARTNERSHIP
60. FOLUSO FADARE ASSOCIATES
61. FUNSO OLADIPO AND PARTNERS
62. GODARET ASSOCIATES
63. GROUP “O”ASSOCIATES
64. HAAT ASSOCIATES
65. HIS MERCIES COST ASSOCIATE
66. HOS- CONSULT
67. ISAAC JAMES ASSOCIATES
68. JABAK CONSULTANTS
69. JIMS PARTNERSHIP
70. JOE LIMEN ASSOCIATES
71. JOSEPH ODU AND PARTNERS
72. KENSTEVE AND ASSOCIATE
73. KTM AND PARTNERS
74. LAB SALAMI AND ASSOCIATES
75. METHOD CONSULTANTS
76. MICHAEL DANIEL ASSOCIATES
77. MIKO ASSOCIATES
78. MONIERO COST ASSOCIATES
79. NAMAK CONSULT LIMITED
80. NIGAQUANTS ASSOCIATES
81. NWIKE, MBA AND PARTNERS
82. O.U. IKPA AND PARTNERS
83. OLUMIDE OLUWOLE ASSOCIATES
84. OYELOLA ASSOCIATES
85. PREMIER DEVELOPMENT CONSULTANTS
86. PROJECT COST ASSOCIATE
87. PROJECT QUANTS PARTNERSHIP
88. PROJECTS MONITORING CONSULT
89. PS ASSOCIATES
90. QUAND BUILD ASSOCIATES
91. QUANTACOST CONSULTING
92. QUANTI-COST PARTNERS

4. List of Building Contracting and consulting firms

S/N NAMES OF FIRMS

1. ALOD CONSULT
2. BELL-X LIMITED
3. BURWOOD CONSTRUCTION LIMITED
4. DOUBLE CHIEF CONSULTANCY SERVICE LIMITED
5. FABEN INTERNATIONAL LIMITED
6. GOD’S MERCY CONSULTANT LIMITED
7. GREEN BROWNW W.A (NIG)
8. HORIZONTAL INTERLINKS GLOBAL RESOURCES LIMITED
9. LABIBIS CONTRACTING SERVICE LIMITED
10. ORGAMITEX CONSULTANT LIMITED
11. PALMYRA CONSTRUCTION NIGERIA LIMITED
12. PEDIOAUTOCRATE SERVICE

13. PRIME WATER VIEW HOLDING LIMITED
14. SALBODI CONSTRUCTION LIMITED
15. TAGFORD NIGERIA LIMITED
16. STINO PARTNERSHIP
17. STONEHOUSE ASSOCIATES
18. STONE 3 ARCHITECTS
19. STONE 3 LIMITED
20. STUDIO STONE DESIGNS
21. STUDIO STYLE+FUNCTION LTD
22. SPACE-TIME CONSULTANTS
23. SYMOLIK DESIGNS AND CONSTRUCTION LIMITED
24. TAIWO KARA ASSOCIATES
25. TAO ALAMUTU AND PARTNERS
26. TAYLAN PRESTON LIMITED
27. TEAM ARCHITECTS
28. TEAM ARCHITECTS LIMITED
29. TERRAFABER LIMITED
30. TEE-M DESIGNS LIMITED
31. THEGRID ARCHITECTS LIMITED
32. TIMPARC INTERNATIONAL LIMITED
33. THE LAWSON+ODEINDE PARTNERSHIP
34. THE SKYBLUE CONCEPT
35. THOM-TOBIAH ASSOCIATES
36. TIPEX PARTNERS
37. TNA ASSOCIATES
38. TOMORO ARCHITECTS
39. TEAM DESIGN ASSOCIATES
40. TROPICAL THRESHOLDS LIMITED
41. TROPICAL SHELTAS
42. TOWRY-COKER ASSOCIATES
43. UNIPLAN KONSULT
44. UNIQUE ARCHITECTS
45. URBAN AND VILLAGE CONSULTANTS
46. URBANALIA CONSULTANTS
47. UUDEX ASSOCIATES
48. VERSATILE CONSULTANTS
49. VICTOR EDOGUN CONSULTANTS AND ASSOCIATES
50. VOEN ASSOCIATES
51. WOLE ESAN ASSOCIATES
52. WOLE OLASEHINDE ASSOCIATES
53. Y-DESIGN CONCEPT ASSOCIATES
54. YU-PET KONSULT
55. YUSUF AND PARTNERS LIMITED
56. ZEMEK NIGERIA LIMITED
57. ZENITH CONSULTANTS
58. STINO PARTNERSHIP
59. STONEHOUSE ASSOCIATES
60. STONE 3 ARCHITECTS
61. STONE 3 LIMITED

62. STUDIO STONE DESIGNS
63. STUDIO STYLE+FUNCTION LTD
64. SPACE-TIME CONSULTANTS
65. SYMOLIK DESIGNS AND CONSTRUCTION LIMITED
66. TAIWO KARA ASSOCIATES
67. TAO ALAMUTU AND PARTNERS
68. TAYLAN PRESTON LIMITED
69. TEAM ARCHITECTS
70. TEAM ARCHITECTS LIMITED
71. TERRAFABER LIMITED
72. TEE-M DESIGNS LIMITED
73. THEGRID ARCHITECTS LIMITED
74. TIMPARC INTERNATIONAL LIMITED
75. THE LAWSON+ODEINDE PARTNERSHIP
76. THE SKYBLUE CONCEPT
77. THOM-TOBIAH ASSOCIATES
78. TIPEX PARTNERS
79. TNA ASSOCIATES
80. TOMORO ARCHITECTS
81. TEAM DESIGN ASSOCIATES
82. TROPICAL THRESHOLDS LIMITED
83. TROPICAL SHELTAS
84. TOWRY-COKER ASSOCIATES
85. UNIPLAN KONSULT
86. UNIQUE ARCHITECTS
87. URBAN AND VILLAGE CONSULTANTS
88. URBANALIA CONSULTANTS
89. UUDEX ASSOCIATES
90. VERSATILE CONSULTANTS
91. VICTOR EDOGUN CONSULTANTS AND ASSOCIATES
92. VOEN ASSOCIATES
93. WOLE ESAN ASSOCIATES
94. WOLE OLASEHINDE ASSOCIATES
95. Y-DESIGN CONCEPT ASSOCIATES
96. YU-PET KONSULT
97. YUSUF AND PARTNERS LIMITED
98. ZEMEK NIGERIA LIMITED
99. ZENITH CONSULTANTS
100. STINO PARTNERSHIP
101. STONEHOUSE ASSOCIATES
102. STONE 3 ARCHITECTS
103. STONE 3 LIMITED
104. STUDIO STONE DESIGNS
105. STUDIO STYLE+FUNCTION LTD
106. SPACE-TIME CONSULTANTS
107. SYMOLIK DESIGNS AND CONSTRUCTION LIMITED

Appendix IV

List of Registered Firms in Ibadan

1. List of Architectural firms

S/N	NAMES OF FIRMS
1.	AECREN LIMITED
2.	AKHIMAX NIGERIA LIMITED
3.	ALAYO CONSULTANT LTD
4.	ALL PURPOSE SHELTERS CONSULT LIMITED
5.	A.M. ARCHITECTS
6.	ANDOK PROJECTS CONSULT LTD
7.	ANNEN ASSOCIATES LTD
8.	ALL WERKS LIMITED
9.	ARABI BELLO AND ASSOCIATES
10.	ARCAID CONSULTANTS
11.	ARCANE ASSOCIATES LIMITED
12.	ARCH + WEB
13.	ARCEPTS LIMITED
14.	ARCHITECTON DESIGN CONSULT
15.	ARCHETYPE A.E.C. LIMITED
16.	ARCHITEAM NIGERIA LIMITED
17.	ARCHITECTURAL AND BUILDING CONSULTANTS
18.	ARCHITECTURAL FACTS LIMITED
19.	ARCHITECTS AND ASSOCIATE CONSULTANTS
20.	ARCH-MERIDIAN CONSULTS LIMITED
21.	ARCTUALS CONCEPTS LIMITED
22.	ASSOCIATED BUILDING CONSULTANTS LIMITED
23.	ARROWHEAD INTERNATIONAL INTEGRATED SCIENCE
24.	ASHLEX SYNERGY LIMITED
25.	ASSOCIATED DESIGN CONSULTANTS
26.	ASSURED DESIGN CONSULTANTS
27.	ATTAH ASSOCIATES
28.	ATOBEKJ ASSOCIATES
29.	ARCFORMS
30.	ARDH CONSULTANTS
31.	ARCHI-PLUS DEVELOPMENT
32.	ARKMAS INTEGRATED SOLUTIONS
33.	ASO RIV CONSULTED
34.	ARTIGRAT LIMITED
35.	AVANT GARDEN DESIGNS LIMITED
36.	BAUHAUS CONSULTING LIMITED
37.	BEBETO PARTNERSHIP
38.	BENGREEN INTERNATIONAL
39.	BESCON PARTNERSHIP
40.	BEZALEEL DESIGN STUDIO
41.	BEYUS NIGERIA LIMITED
42.	BLACINE ARCHITECTS LIMITED
43.	BLOEX BLUE SERVICES LIMITED
44.	BINATARE CONSULT
45.	BOM ASSOCIATES
46.	BONTAN CONSULTANTS
47.	BORNARC CONSULTANTS LIMITED

48. CANONIC ASSOCIATES
49. CAPITAL PROJECTS CONSULTANTS
50. CEA DESIGN WORKS LIMITED
51. CHUKS AND DE-CREW SERVICES LIMITED
52. CONTINENTAL SHELTER ASSOCIATES
53. COLLABORATIVE DEVELOPMENT SERVICES LIMITED
54. CHILOKAR NIGERIA LIMITED
55. CHRIS OHIKERE AND ASSOICIATES
56. COMPLETE ARCHITECTURAL SERVICES LIMITED
57. COMPTON PROJECTS LIMITED

2. List of Engineering Firm

1. 1ST CONCEPT ASSOCIATES (NIG.) LTD.
2. CONSTYLE SERVICES
3. CONTEMPORARY CONSTRUCTIONS AND BUILDING DESIGN LIMITED
4. COSMO BASE CONSORTIUM LIMITED
5. CRE-8-TIVE BLUEPRINTS
6. CREATION CONSULTANT
7. CREATIVE SHELTERS
8. CROWN ASSOCIATES LIMITED
9. CUBE CONSULTANTS NIGERIA
10. CUBISM LIMITED
11. D AND B LIMITED
12. DEAKITEX COMPANY
13. DECKARD TYLER LIMITED
14. DEFINITE STROKERS NIGERIA LTD
15. DELE ODEDIRAN ARCHITECTS CONSULTANTS
16. DELTON ASSOCIATES LIMITED
17. DENGARC ASSOCIATES
18. DERINOKA INTEGRA
19. DESERECT NIGERIA LIMITED
20. 3D-DESIGN CONCEPTS LTD
21. DESIGN AGE CONSULTANT LIMITED
22. DESIGN AND DWELL ASSOCIATES LTD
23. DEXTRA PROJECTS LIMITED
24. DEZUE ARKI-CONSULT LIMITED
25. D. MATIZ AND DEIORI CONSULTING LTD
26. DOLAPO AKEREDOLU AND ASSOCIATES
27. DOMUS-KRAFT TURKEY PROJECT LIMITED
28. DONED CONSULT
29. DOZARCH CONSULT LIMITED
30. DYNAMIC LEON PROJECTS LIMITED
31. E.F. PROJECTS LIMITED
32. EDIFICES DESIGNS
33. EENARC CONCEPTS LIMITED
34. EL-MANSUR ATELIER CO
35. EMEKA NWANDU ARCHITECTS
36. ENDY-ILLOY AND ASSOCIATES
37. ENICS CONSULT LTD

38. ENVIRONMENTAL CONCEPTS ASSOCIATES
39. ENVIRONMENTAL EXPRESSIONS LIMITED
40. EYEBROTECTURE AND ASSOCIATYES LTD
41. EQUILATERAL ARCHITECTS LIMITED
42. ES ASSOCIATES LIMITED
43. FENTAN AND ASSOCIATES
44. FM + ARC CONSULT LIMITED
45. FORMS AND SPACES LIMITE
46. FRANK AND FRIENDS (WA) LIMITED
47. FROMEB ASSOCIATED NIGERIA
48. GAFOWNY ASSOCIATES
49. GAFCON SYSTEMS LIMITED
50. GENOOU CONCEPTS
51. GEORGE ONIOMOH AND ASSOCIATES
52. GIYONT KUBA LIMITED
53. GLOBARCH ASSOCIATES
54. GOMIC CONSULTS
55. GEOMETRIX CONSULTANTS AND BUILDERS LIMITED
56. GRAND STROKES LIMITED
57. GROUP ONE DIMENSION LIMITED
58. HACIENDA ASSOCIATES
59. HABIMOULDS LIMITED
60. HABITAT ASSOCIATES
61. HAJA CONSULT (TURKEY PROJECT) NIGERIA LIMITED
62. HAR MONIC ASSOCIATES
63. HI-TECH STUDIO NIGERIA LIMITED
64. HM AND ARCHITECTS LIMITED
65. HOMEPLAN ASSOCIATES

3. List of quantity surveying firms

S/N NAMES OF FIRMS
1. ABKA COST CONSULTANTS
2. ABRAHAM COST CONSULTANTS
3. ADO AND PARTNERS
4. AESM PARTNERSHIP
5. ALANS ASSOCIATE
6. AMAQUANTS ASSOCIATES
7. ARQUENG CONSULTANTS
8. BILLS AND MEASURES
9. BUCHI AND ASSOCIATES
10. CAPITAL PROJECTS AND RESOURCES ASSOCIATES
11. COMSEG ASSOCIATES
12. CONSULT BEST PARTNERSHIP
13. COSSETS CONSULTANT
14. COST BENEFIT CONSULTANTS
15. COST PLANNING CONSULTANTS
16. CYNERGY ASSOCIATES LTD

17. DESIGN COST ASSOCIATES
18. DODO MAAC CONSULT
19. EL-RUFAI AND PARTNERS LTD
20. FEESE, MUSA AND PARTNERS
21. FISSY AND PARTNERS
22. FOMAR ASSOCIATES
23. GEKLA ASSOCIATES
24. HANIA ASSOCIATES
25. IFEANYI ANAGO AND PARTNERS
26. IN-HOUSE CONSULTANTS
27. INTEGRATED PRACTICE CONSULTANTS
28. INTEGRITY COST ASSOCIATES
29. ISEJ ASSOCIATES
30. JAMKOLDIP CONSULT
31. JIREHOSA COST ASSOCIATES
32. JOSEPH AFE AND PARTNERS, JOSEPH AFE
33. KABOLA ASSOCIATES
34. KALABAL ASSOCIATES
35. KHALILULLAHI ASSOCIATES

4. List of building and contracting firms

S/N NAMES OF FIRMS

1. AKIN-LANE CONSULTANTS LIMITED
2. AMSOMOPS ENTERPRISES LIMITED
3. ANNAI LIMITED
4. ASBA SYNERGY CONCEPT LIMITED
5. BINANI NIGERIA LIMITED
6. BREM TECHNOLOGIES LIMITED
7. BRUNEL ENGINEERING AND CONSULTING LIMITED
8. CRESTHILL ENGINEERING LIMITED
9. DEUTERON NIGERIA LIMITED
10. FAFU RELIABLE HOMES LIMITED
11. G-NETWORK PROJECTS LIMITED
12. IMPACTO BUILDING AND CONSTRUCTION
13. INTEGRATED DEVELOPMENT SERVICES LIMITED
14. LUXURY BUILDINGS AND ACCESSORIES LIMITED
15. MEDUOZA AND AMEDARI NIGERIA LIMITED
16. QUEST RESOURCES CONSULTS LIMITED
17. SAGETO LIMITED
18. SAMSON OPALUWAH CONSULT LIMITED
19. SANTRO LIMITED
20. SHELTERS BUILDERS AND FACILITY MANAGEMENT CONSULTANT LIMITED
21. STAGE ONE INTERNATIONAL (NIG) LIMITED
22. STE ROBERTS LIMITED
23. STRONGMARK NIGERIA LIMITED
24. TIANJIN-YUYANG CONSTRUCTION ENGINEERING COMPANY LIMITED
25. TRAMASCO NIGERIA LIMITED
26. TRU-KONSULT INTERNATIONAL
27. TRUMAN LIMITED

28. UJAT NIGERIA LIMITED
29. VALUE BUILDERS NIGERIA LIMITED
30. YAMIZA LIMITED
31. YAR-BAKHAT COMPANY LIMITED
32. KOST ASSOCIATES
33. LEO IKE ASSOCIATES
34. LUWAB ASSOCIATES
35. MABOD ASSOCIATES
36. MAN ASSOCIATES
37. MECHACH PHILIPS CONSULTING
38. M-GROUP ASSOCIATES
39. MOHAMMEDDEEN MUSA AND PARTNERS
40. MOSALAB CONSULTANTS
41. MTI PARTNERSHIP
42. KOST ASSOCIATES
43. LEO IKE ASSOCIATES
44. LUWAB ASSOCIATES
45. MABOD ASSOCIATES

Appendix V

List of Registered Firms in Abeokuta

1. List of Architectural firms

S/N NAMES OF FIRMS

1. A.A SUSCONS LIMITE
2. ABODES ARCHITECTS
3. AF. PARTNERSHIP
4. ALLIED ASSOCIATES LIMITED
5. ALLIED CONSULTANTS LIMITED
6. ALTIGRA NIGERIA LIMITED
7. AM DESIGN CONSULT
8. AQUELLA CONSULTANTS
9. ARCHON NIGERIA LIMITED
10. ARCHICAD PROJECTS NIGERIA LTD
11. ARCHIPLAN INTERNATIONAL LTD
12. ARCKY DECK ASSOCIATES
13. ARCHI-TRI MULTIDIMENSION
14. ARCTRACK ASSOCIATES

2. List of Engineering Firms

1 ARKI-TRENDZ CONSULTS LIMITED
2 ARTEC PRACTISE LIMITED
3. ARQIMEN CONSULTANTS LIMITED
4. ARC-PROJECT NIGERIA
5. BAYOM AND ASSOCIATES
6. BEST DESIGNS CONSULT LIMITED
7. BESTARC INTERNATIONAL
8. BUILD-DESIGN LIMITED
9. BUILDING ANATOMY LIMITED
10. COMPONENTS CONSULTS
11. CLASSIC PROFESSIONAL CONCEPT
12. COPLAN ASSOCIATES
13. CURRENT DESIGN STUDIOS
14. DAR INTEGRATED ARCHITECTS AND CONSULTANT LIMITED
15. DEENARC CONSULTANTS

3. **List of Quantity Surveying firms**

S/N NAMES OF FIRMS

1. ABDUSSALAM AND PARTNERS
2. AG-PARTNERSHIP
3. ALI AND JOHN ASSOCIATES
4. AMAK CONSULTANTS
5. ASSOCIATED COST CONSULTANT
6. AXIS CONSULTING
7. BITRUS GAMBO AND ASSOCIATES
8. BM CONSULT
9. COST DESIGN PRACTICE PARTNERSHIP
10. EXCELQUANT COST CONSULTANTS
11. GIMBA AND PARTNERS
12. IN-COST CONSULTANTS

13. INTEGRATED COST ASSOCIATES
14. JAMO AND ASSOCIATES
15. KONTI-SAB ASSOCIATES
16. M AND A ASSOCIATES
17. M.M. AHMADU AND PARTNERS
18. MAYER AND BRINDLE
19. MQX AND ASSOCIATES
20. MULTI CONSULTS PARTNERSHIP
21. PACKAGE CONSULTANTS
22. PREMIER QU-ESS ASSOCIATES
23. PRICEHOUSE ASSOCIATES
24. PRIME AND BELL PARTNERSHIP
25. PRISMS CONSULTANTS
26. PRODEL CONSULTANTS
27. PROJECT COST CONSULTANTS LTD
28. ROMAN ASSOCIATES
29. Q. ASSOCIATES
30. QUANT-EST PARTNERSHIP
31. RASH PARTNERSHIP
32. ROSANA COST CONSULTANTS

4. **List of Building Contracting and Consulting firms**

S/N NAMES OF FIRMS

1. HABITAT GLOBAL SERVICES NIGERIA LIMITED
2.
3. MFB PROPERTIES LIMITED
4. SHEHIM VENTURE
5. YUBA CONSULTANT LIMITED
6. NONNAM CONSULTANTS
7. OLGA GROUP
8. PROQUEST CONSULTANTS
9. QUANPRO GOBAL RESOURCES
10. QUANT KONSULT
11. QUANTI-TEQUE ASSOCIATES
12. RASY ASSOCIATES
13. ROYAL COST CONSULTANTS ASSOCIATES
14. SUNDAY ELUFIOYE AND ASSOCIATES
15. TECHGRADE CONTRACT ANALYSIS CONSULTING
16. UCHECHUKWU AND PARTNERS
17. UNIFIED QUANTITY SURVEYINGS
18. UNIQ PROJECTS KONSULT
19. UNITS ENVIRONMENTAL SCIENCES
20. URBAN PROJECTS SERVICES ASSOCIATES
21. WARD AND PARTNERS LTD
22. Y.S. ASSOCIATES
23. ZEEGA ASSOCIATES
24. HOUSEHOPE CONSULT LIMITED
25. HUEY AND KAL LIMITED
26. HUGO AND PARTNERS

27. HURAM ARCH-BUILDERS LIMITED
28. IBROUMAR ASSOCIATES LIMITED
29. IOU CONSULTS NIGERIA LIMITED
30. ICONIC CONSULT
31. ICONS ARKITEKTURE-OLA LIMITED
32. IDEAL SPACES LIMITED
33. INTEGAX RESOURCERY LIMITED
34. INTER-FACE PROJECTS LTD
35. JONI CONSULTANTS
36. JACQUELINE JACOB CONSULT
37. J.C. DESIGN CONCEPTS LIMITED
38. JERMAN CONSULT LTD
39. KINETO CONSULTS LIMITED
40. KHADI DESIGNS AND CONSULT
41. JUXTAPOSE CONSULTS
42. KAPITAL PROJECTS AND RESOURCES ASSOCIATES
43. LANDEV PARTNERS
44. LANDMARK TURKEY PROJECTS LTD
45. LEONARD ASSOCIATES
46. LAND BUILDS CONSORTIUM LIMITED
47. LINEAR REFORM DESIGN AND BUILD LTD

Appendix VI

List of Registered Firms in Ado-Ekiti

1. List of Architectural firms

S/N	NAMES OF FIRMS
1.	ARCHIBASE LIMITED
2.	ARCHIMAGE LIMITED
3.	ARCEZEE LIMITED
4.	ASTERICS - 4 ATTAH ASSOCIATES
5.	A-VISUALS AND ASSOCIATES
6.	ASSOCIATED DESIGN CONSULTANTS
7.	ARKISPACES CONSULTANTS

2. List Engineering Firms

1.	BONSPACE ASSOCIATES
2.	CARDOZI GROUP CONSULTANT
3.	CAMP PARTNERSHIP
4.	CHU-ILCA ASSOCIATES
5.	CIO CONSTRUCTS

3. List of Quantity Surveying firms

S/N	NAMES OF FIRMS
1.	ANDEE AND PARTNERS
2.	BROSPAL PARTNERSHIP
3.	COSQUANT ASSOCIATES
4.	ECCON ASSOCIATES
5.	EMEKEN QUANTITIES
6.	GOCH ASSOCIATES
7.	KOCH ASSOCIATES
8.	KRISCON ASSOCIATES

3. List of Building Contracting and Consulting firms

S/N	NAMES OF FIRMS
1.	ANDEE AND PARTNERS
2.	BROSPAL PARTNERSHIP
3.	COSQUANT ASSOCIATES
4.	ECCON ASSOCIATES
5.	EMEKEN QUANTITIES
6.	GOCH ASSOCIATES
7.	KOCH ASSOCIATES
8.	KRISCON ASSOCIATES
9.	MACILDON GROUP CONSULT
10.	NEK CONSORTIUM

Appendix VII
List of Registered Firms in Akure

1. List of Architectural firms

S/N NAMES OF FIRMS

1. ARCH-BIZ CONSULT
2. ARCKNATURE CONSULTING NIGERIA LIMITED
3. ARCHITECRONIX LIMITED
4. ATEJ CONSULT

2. List of Engineering Firms

1. BECTARG ASSOCIATES
2. BLABLUE RIBBON ARCHITECTS
3. BLUE COLLAR LIMITED
4. BONS ASSOCIATES
5. CAP CONSULTANTS
6. COSMOPOL CONSULT
7. CUSTOM REALITIES

3. List of Quantity Surveying firms

S/N NAMES OF FIRMS

1. AES CONSULTANTS
2. AMAN ASSOCIATES
3. BENE ASSOCIATES AND BRAVO CONSULT

4. List of Building Contracting and Consulting firms

S/N NAMES OF FIRMS

1. HARPERS CONCEPT LIMITED
2. KLEM KATHRINES ASSOCIATES
3. LAX NIGERIA LIMITED
4. MEGASTAR TECH AND CONSTRUCT COMPANY LIMITED
5. SAVANT BUILDERS AND CONTRACTORS LIMITED
6. SOLOSMOND NIGERIA LIMITED

APPENDIX VIII

List of Registered Firms in Osogbo

1. List of Architectural firms

1. BECTARG ASSOCIATES
2. BLABLUE RIBBON ARCHITECTS
3. BLUE COLLAR LIMITED
4. BONS ASSOCIATES
5. CAP CONSULTANTS
6. COSMOPOL CONSULT
7. CUSTOM REALITIES
8. D-19TH ARKITEKTS LIMITED
9. DESIGN CONSULTANCY SERVICES
10. DESIGN INFINITUM LTD
11. DETAILS 2 DOT DEVELOPMENT NIGERIA LIMITED
12. DIKE & PHIL ASSOCIATES LIMITED
13. DIMMS CONSULTANTS
14. DIVINE DIMESIONS CONSULTS

2. List of Engineering Firms

1. NICE KONSULT COMPANY
2. NUGEL C. ASSOCIATES
3. ONWUCHEKWA & DUBOYE ASSOCIATES
4. PACS ASSOCIATES
5. PEAK CONSULT
6. PELICON ASSOCIATES
7. PRAGMATIC DESIGN CONSULT SERVICE
8. PARMEK ASSOCIATES

3. List of Quantity Surveying firms

1. CHAZDIAMES ASSOCIATES
2. COST MASTER ASSOCIATES
3. DEVELOPMENT COST BANK ASSOCIATES
4. DIMAN QUANTITY SURVEYINGS
5. ENVIRONMENTAL SURVEYINGS
6. FEG ASSOCIATES
7. FRANCIS FORTETA PARTNERSHIP
8 KEDEX COST CONSULTANTS
9. KPONITE ASSOCIATES
10 LOY-COST ASSOCIATES
11 NUKS ASSOCIATES
12. NZEMEK ASSOCIATES

4. List of Building Contracting and Consulting firms

1. QUANTAE CONSORTAE
2. SAMCONJIS AND ASSOCIATES
3. SIGNCOST ASSOCIATES
4. STANDARDS CONSULTANCY SERVICES
5. EMERUWA OGECHI & PARTNERS LTD

Bio-data

A. Personal Data

Name Akeem Akinola **ALAJE**

Contact Address Department of Architecture, Lead City University, Nigeria

+234-7068420676/ alajephemmy@gmail.com

Date and Place of Birth: 4th Feb. 1988; Ikire

Nationality Nigerian

Present Position Lecturer II

Faculty Faculty of Environmental Management and Design

Department Architecture

Next of Kin: Ibukunoluwa Grace ALAJE

Address(Next of Kin): No 15, Zone J Akardi Estate, Elenusonso, Ibadan

B. Academic/Professional Qualifications (with dates and institutions)

M.Tech (Architecture) Ladoke Akintola University of Technology Ogbomoso.

2015 - 2021

B.Tech (Architecture)/2[11] Ladoke Akintola University of Technology Ogbomoso.

2009 - 2015

NECO/SSCE Fatima College Ikire, Osun State, Nigeria.

2001 - 2007

Pry School Leaving Cert. S.U.D Primary School Akinlalu, Osun State, Nigeria.

1995 – 2001

C. Certifications

Project Management Professionals (PMP) - 2023

Chartered Human Resources Consultant (Ch. HRC) - 2023

D. Work experience

Post	Organization	Date
Lecturer II	Lead City University, Ibadan	01/11/2023- Date
Lead Project Architect	SignetArchitects & Properties Limited	14/09/16 – 01/11/202
Internship	International Architects	04/05/13 - 20/11/14

E. Membership of Professional Bodies

i. Full Membership: Project Management Institute (PMI)/8773664

ii. Full Membership: Chartered Institute of Contract Project and Facility Management (0008977)

iii. Associate membership: Nigerian Institute of Architects (NIA)

iv. Full Membership: Chartered Institute of Human Resources Management (106075)

F. Capacity Building Trainings Attended with Dates

i. Business Leadership Development Program at Rome Business School/March 1st – May 30th,2023

ii. Mapping Research Needs for Early Career Academics in the University by ACU. UK/29 August, 2017

iii. Peace Education & Peer Mediation at Justice Development and Peace Commission Ikire/27th -30th September, 2005

G. Publications

Current Research

Alaje A.A (2023). PhD Architecture, Lead City University Ibadan, Nigeria.

Title of Thesis: Adoption of Building Information Modelling (BIM) in the Building Industry- Southwest Nigeria. Duration of Programme: 2021-2024 (3 yrs.)

Supervisor: Dr. Oludare Obaleye

Submitted Thesis/Dissertation

i. **Alaje A.A. (2021). M.Tech Architecture thesis, Ladoke Akintola University of Technology Ogbomoso.**

   Title of Thesis: Evaluation of Youths' Preference for Vocational Education as a Design Consideration for Vocational Training Centre in Ogbomoso, Nigeria.

   Date of Completion: July, 2021

   Sole Supervisor: Prof.AM.O Atolagbe

ii. **Alaje A.A (2015). B.Tech Architecture thesis, Ladoke Akintola University of Technology Ogbomoso.**

   Title of Thesis: Evangel Secondary School Ibadan.

   Date of Completion: February, 2015

   Sole Supervisor: Arc. Akangbe (Mnia)

Published Journal Articles:

i. **Alaje, A. A.,** Adedire, F.M., & Dorcas, O. (2023). An Investigation of Different BIM Software Applications and Level of Usage Among the Professionals in The Nigerian Aec Industry : A Case Study of Oyo State. *Journal of Archiculture*, *5*(March), 15–26.

ii. **Alaje, A. A.,** Adedire, F.M., & Oluwole, A.A (2023). Building Information Modeling (BIM) Adoption in Architectural Firms in Ibadan, Southwest Nigeria. *Journal of Environmental Technology*, 1*5*(2)

iii. **Alaje, A. A.,** & Adedire, F.M (2023). Factors Limiting Adoption of BIM in Developing Country. *Journal of Environmental Sciences*

-- --

Signature **Date**

The University Compliance Certification

This is to certify that, Akeem Akinola ALAJE with matriculation number LCU/PG/03624 carried out this research work titled 'Assessment of Building Information Modeling (BIM) Adoption in the Building Industry in Southwest Nigeria' in the Department of Architecture, Faculty of Environmental Design and Management, Lead City University, Ibadan, Oyo State, is in full compliance with the approved University format and style.

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Signature **Date**