EFFECTS OF ADOPTING BUILDING INFORMATION MODELLING (BIM) IN THE NIGERIAN CONSTRUCTION INDUSTRY

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY (M.Tech) IN PROJECT MANAGEMENT

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ABSTRACT

Building Information Modelling (BIM), whichis a digital representation of physical and functional characteristics of a facility throughout its life cycle, is a modern building delivery technology embraced globally by the construction industry. This study aimed to assess the adoption of BIM in the Nigerian Construction Industry (NCI), in order to reveal the effect of BIM adoption on projects carried out by construction professionals. Three objectives that were formulated towards achieving this aim included: ascertaining the level of BIM in operation, determining the impact of BIM in the project life cycle, and ascertainingthe existence of government construction strategy for BIM. The study adopted a quantitative research design that was based the use of structured questionnaires. A convenience sample of relevant professionals in construction industry who could be accessed electronically was built up through a snowballing approach, whicheventually yielded a total of 252 professionals. The data gathered from this sample through a questionnaire survey was analysed using descriptive statistical method (Mean Item Score and Standard Deviation) and the results were presented using tables and charts. The study found that BIM awareness and acceptance are at a medium level; only 'AutoCAD' BIM software enjoyed a 'High' frequency of useinthe NCI. BIM adoption had a noticeable impact in four reviewed aspects of project performance; 'Greater control', 'Improved collaboration', 'Conflict resolution', and 'Reduction in labour'. The study concluded that BIM use in the NCI is still at a rudimentary level, although great potential for improvement exists, if the right environment (political, legislative, contractual, technical) is provided; very little evidence exists however of any government strategy for BIM in the NCI. It was recommended that the Federal and State governments should promulgate an Implementation Strategy Plan for BIM;Employers could subsidise BIM costs throughPreliminaries items in construction contracts; construction professional bodies must prioritize the adoption of BIM by their members. It is suggested that future studies should focus onthe effect of type and size of projects on the adoption of Building Information Modelling (BIM) within the Nigeria Construction Industry.

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CHAPTER 1

1.0 INTRODUCTION

1.1 Background to the Study

Building Information Modelling (BIM) is a modern building delivery technology which is embraced by the construction industry globally (Yusuf *et al*., 2015). Internationally, the building industry is transforming rapidly with the introduction of BIM (Onungwa and Uduma-Olugu, 2016). It is a digital model full of information for the purpose of construction and management of the project throughout its life cycle (Yusuf *et al*., 2015); it is a digital representation of physical and functional characteristics of a facility (BSA, 2007). This embrace by the construction industry became necessary because of the near gross inefficiency associated with construction activities and project delivery over the years.

The construction industry is one of the major industries contributing significantly to the economy, in terms of GDP for most countries, especially developing countries like Nigeria. Despite this fact, the industry is not maximizing its full potentials. This has been attributed to some factors, among which is the fragmented process of design, procurement, construction, and project delivery (Khalfan and Anumba, 2000). In addition, the construction industry has faced so many criticisms across the globe for its inefficiency and lack of productivity, which have been attributed to its fragmented nature of project delivery.

Building Information Modelling (BIM) has become the measure of yardstick and an international benchmark for efficiency in Architectural, Engineering and Construction (AEC) and host of other building services. It is a platform that brings collaboration and integration of environmental professionals and all other stakeholders (Yusuf *et al*., 2015). BIM is said to encompass all phases of project development from investment conceptual stage, through to architectural, civil/structural, mechanical/electrical, cost involvement and analysis, procurement, tendering and award, construction to completion and occupation, facility maintenance and operation, and finally the demolition of the building with a positive resultant returns of investment at the end of its lifespan(Yusuf *et al*., 2015).

Series of studies have also revealed that BIM is having the potential to significantly change and improve performance and documentation in the construction industry, and this will invariably reduce inefficiencies, enhancing productivity and increasing collaboration and communication, with the intention that BIM will achieve decreased project costs, increased productivity and quality and reduce project delivery time(Yusuf *et al*., 2015).

The construction industry in Nigeria grapples with the challenges of inefficiency necessitated by several factors including time overrun, cost overrun, high level waste, high labour cost, deviations, variations/claims, inadequate control of the construction process, lack of seamless collaboration between agents, conflicts and clashes, as well as high level errors and risks. The construction industry experiences many changes concerning how to increase the efficiency on its processes (Manza, 2016). Building information modelling (BIM) is a product of the general improvement in technology that is created to encourage teamwork and collaboration during the design and construction period (Onungwa and Uduma-Olugu, 2017). BIM promotes a modern collaborative method of working in the Architectural, Engineering and Construction (ACE) areas where each participant that has assigned an individual task, should adopt a new behaviour based on the interchange of knowledge and information, with the aim of overcoming new challenges and increment the common benefits of the group.There is also a BIM level to attain and with its associated parameters scaled to be adjudge BIM compliant (i.e. BIM level 2) at the moment.

1.2 Statement of the Research Problem

Among professionals interested in construction in Nigeria, there is limited use of BIM due mainly to their inability to keep pace with the modern advancement in technology, their level of awareness about BIM is low (Onungwa and Uduma-Olugu, 2017). Quite a number of studies on BIM in the Nigerian construction sector have been attempted; some of these studies focused on areas such as BIM and life cycle of the project (Onungwa and Uduma-Olugu, 2017), BIM and adoption factors for construction industries in Nigeria, (Mohammad, 2018), contractors' perception of BIM implementation in Nigeria (Ibrahim *et al*., 2014).

However, this research shall focus on assessing BIM adoption in the Nigerian construction industry measuring it by several international standard parameters available, determine the level of adoption so far, determine what is the government strategic construction BIM implementation strategy in place and what the government and AEC practitioners in Nigeria should be doing to move up to the next BIM adoption level.

1.3 Aim and Objectives

The aim of this study is to assess the adoption of Building Information Modelling (BIM) in the Nigerian Construction Industry (NCI), in order to revealthe effect of BIM adoption on projects carried out by construction firms. The objectives of this research are to: -

i. ascertain the level of BIM in operation in the Nigeria Construction Industry;
ii. determine the impact of the level of BIM adoption in the project life cycle of construction projects and
iii. ascertain the existence of government construction strategy for the adoption and implementation of BIM in the Nigerian construction industry.

1.4 Research Questions

i. What is the level of BIM adoption in operation in the Nigerian Construction Industry?
ii. What is the impact of the level of adoption of BIM in the construction industry in the project life cycle of projects in Nigeria?
iii. Is there a construction implementation strategy by the Nigerian government for the adoption and implementation of BIM in public sector projects in Nigeria?

1.5 Need for the Study

The Nigerian construction industry especially the Architecture, Engineering and Construction (AEC) sector is faced with so many challenges (Ogunmakinde andUmeh, 2016). Efforts at adopting BIM in Nigeria's private and public sector and amongst different building professionals (Architects, Quantity Surveyors, Civil Engineers, etc.) have been very slow (Alufohai, 2012). Building Information Modelling (BIM) is a concept that is transforming the way construction is done internationally (Onungwa and Uduma-Olugu, 2017).

In adopting and implementing BIM in the construction industry in Nigeria in the bid to overcome these challenges, there is a need to measure and ascertain what is the level of BIM adoption in the Nigerian construction industry at the moment and its impact so far as a solution to bringing effectiveness and general improvement to the construction industry in Nigeria in order to proffer recommendations on the way forward in moving to the next BIM level.

1.6 Hypothesis

H0: There is no significant relationship between the adoption of BIM and its impact in the Nigerian construction industry.

H1: There is a significant relationship between the adoption of BIM and its impact in the Nigerian construction industry.

1.7 Scope of the Research

The scope of this research focused on data gathered and analysed through structured questionnaire in the professional areas including in the Architectural, Engineering, Building, Quantity Surveying, Services and Project management operating as either contractors, consultants or specialist at different projects spread across the demography as listed below; whether they only operated locally or those with international presence.

The research also covered projects whether they were public or private sector projects in its analysis with Architectural, Engineering and Construction (AEC) professionals with experiences from as low as 2 – 5 years to those with over 15 years' experience.The research gathered its analysis from companies/firms in the Nigerian Construction Industry (NCI) in the following North Central states comprising Niger, Nassarawa states and Abuja, the Federal Capital Territory. This is because most construction and consulting firms have their head offices or branches located in Abuja and these surrounding states and hence a high concentration of construction professionals are located within these states.

1.8 Significance of the Research

According to Onungwa and Uduma-Olugu(2017), BIM is fast dictating the pace of professional work and changing the process of design and construction of buildings in the construction industry. Also according to (Hassan and Yolles, 2009), the 3D modelling process extends to scheduling and sequencing (4D), cost estimating (5D), sustainable design also termed Green Design (6D) and facility management (7D).

This knowledge will help AEC practitioners further see the need to adopt and implement BIM in their processes; the research will also help to correctly situate the level of BIM adoption presently in Nigeria. This will present the true state of level of BIM adoption and its implementation in Nigeria's construction industry and proffer recommendations on how to move to the next BIM level.

The research will also help to catalogue the hindrances affecting the adoption and implementation of BIM in the Nigerian Construction industry, this will help researchers, AEC practitioners, government and all stakeholders come to terms with the impact whether positively or negatively of BIM adoption in the Nigerian construction industry.

In 2016, in the United Kingdom, the government mandated the application of BIM, and as a result the adoption rate increased from 60% to 95% for last three years (Waterhouse and Philip, 2016). The outcome of this research will also ascertain the Nigeria's government's construction strategy in adopting BIM in public sector AEC projects and also make recommendations on why this is necessary.

Researchers, industry professionals, government and indeed all stakeholders in the construction industry will benefit immensely from the findings of this research work in areas of BIM implementation in private/public sector projects, the stage(s) of the project life cycle where BIM has found most implementation, barriers to BIM implementation in the Nigerian construction industry as well as the most used BIM softwares among AEC practitioners in the construction industry in Nigeria. Other important areas will touch on whether local companies are the ones with higher BIM adoption or those with international presence, as well as establishing the various means through which AEC obtain BIM training/knowledge.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The Nigerian Construction Industry

The construction industry plays a pivotal role in the economic development process of anynation. (Lam, 2016). It provides constructed space for economic activities, employment and utilizes goods and services of other sector of the economy during the production process (Lam *et al*.,2016).

The construction industry in Nigeria is an important industry which impacts positively on the national economy contributing 3.12% to the national economic growth as estimated in the rebased nominal GDP of 2013 (NBS, 2014). The growth of the construction industry is rising at a steady rate and is predicted alongside Indian construction industry to enjoy higher growth rate than china between 2009 and 2020 in terms of construction output (Saka and Olanipekun, 2020). Among fourteen sectors with positive rates, construction was the sixth position with 2.3% growth rate according to National Bureau of Statistics (Statiscience, 2012).

The construction industry plays a significant role in the national economy and economic development of any nation. Its significance is due to the role it has in the economy, but that role varies greatly from one nation to another. In developing countries, the construction industry is a very important sector providing mainly new infrastructure in the form of roads, railways, airports as well as new hospitals, schools, housing and other buildings (Dakhil 2013). The construction industry is undergoing a radical change as project owners are demanding for more project visibility at lower cost and better risk management; this has increased the use of new technologies in project implementations (Ogwueleka and Ikediashi, 2017).

2.2 Building Information Modelling (BIM)

According to Autodesk, the developer of various Building Information Modelling (BIM) tools, "BIM (Building Information Modelling) is an intelligent 3D model-based process that gives architecture, engineering, and construction (AEC) professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure" (Autodesk, 2017).

Building Information Modelling (BIM) is an innovative approach in architectural, engineering and construction industry as a modelling technology which encompasses AEC digital data throughout the construction life cycle (Mohammed *et al*, 2018). Building information Modelling (BIM) is one of such innovative processes that promises to bring about the continuous improvement and desired change in the construction industry and revolutionize the processes of its operation to achieve better collaboration between project parties and ensure successful project delivery. BIM stimulates the construction activities in a virtual environment. With BIM technology, an accurate virtual model of a building known as Building Information Model is digitally constructed and used to support the design, procurement, fabrication and physical site construction activities required to realize the structure (Ibrahim *et al*., 2014).

BIM has also been defined as the digital representation of the physical and functional characteristics of a facility, which serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward (Building Smart, 2010). And according to (Ibrahim and Abdullahi, 2016), BIM is the most recent technological innovation developed to support designs, construction and operation of building and engineering projects in a virtual environment using intelligent objects. With BIM, both 2D and 3D drawings can be created as by-products of its design process. Design views can automatically be generated from single foundational database; and all other form of analysis such as clash detection, constructability analysis and more, can be undertaken in a BIM environment.

Globally, BIM has already existed more than twenty years (Hadzaman*et al*., 2015). Many developed economies of the world have recorded impressive outcomes by implementing BIM in their construction practices (Ibrahim *et al*., 2014). The idea of BIM was led by the United States (Smith, 2014). United Kingdom (Waterhouse and Philip, 2016); Norway, Finland and Denmark (Smith, 2014), are other leaders in BIM adoption and implementation.

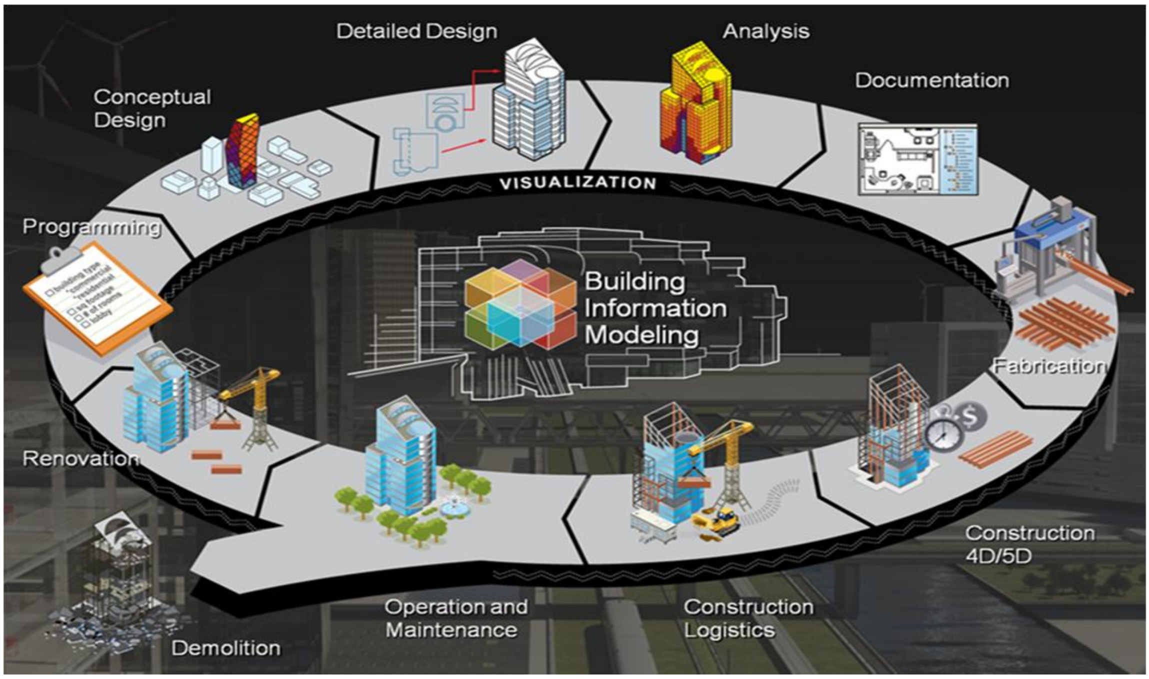

Figure2.1: Schematic Representation of BIM Interaction

Figure 2.2: BIM for Infrastructure

According to (Hamma-Adama andKouider, 2018), Figure2.1 presents a representation of BIM schematics from inception through the construction process, to completion and to the entire lifecycle of a building. Figure 2.2 presents an outlook of infrastructural engineering design in a BIM environment and Figure 2.3 presents how information isshared (in the central model) between the project stakeholders.

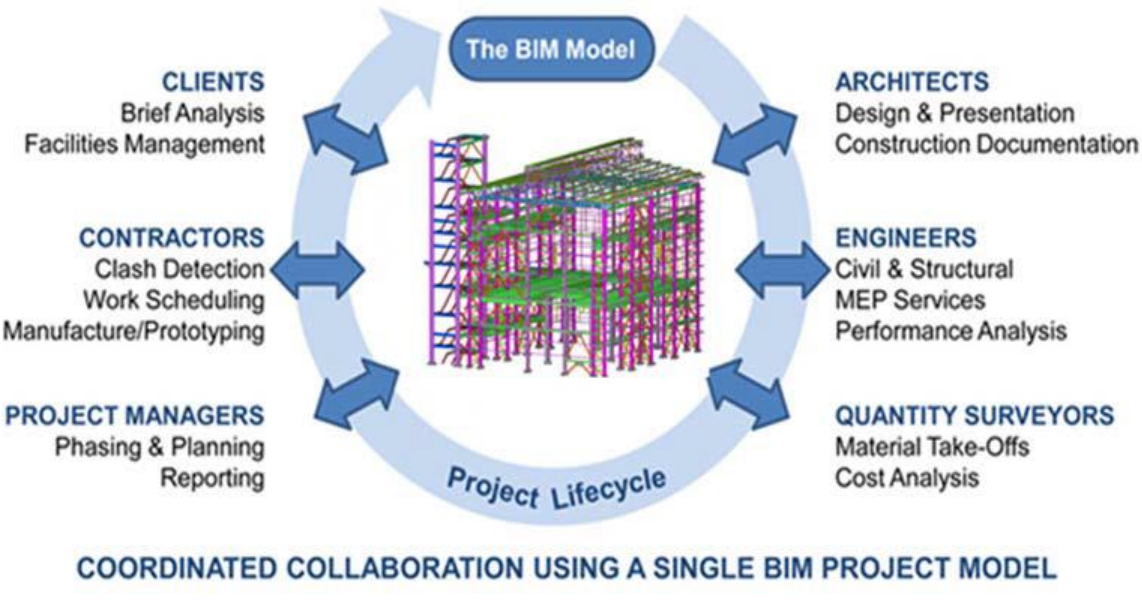

Figure 2.3: Schematic representation of data exchange and collaboration

There are so many professional BIM software available in the market today complying with all digital delivery requirements. Some of the BIM software are listed below:

i. ARCHICAD: is an architectural BIM CAD software that offers computer aided solutions for handling all common aspects of aesthetics and engineering during the whole design process of the built environment (Wikipedia, 2020).

ii. Vector works: a 2D drafting, 3D modelling, BIM and have rendering capabilities. A design software that delivers a flexible and collaborative design process to architecture, landscaping and entertainment professionals, (Vectorworks, 2020).

iii. Autodesk Revit: Revit is BIM software offering a multi – disciplinary and collaborative approach to design and construction projects. Revit empowers the AEC practitioners to produce a consistent, coordinated, and complete model – based designs for buildings and infrastructure (Autodesk, 2020).

iv. Navisworks: a 3D design review that combine design and construction data into a single model. Identify and resolve clash and interference problems before construction. (Autodesk, 2020).

v. Sketch up: a premier 3D modelling computer programme for a wide range of drawing application.

vi. Allplan: a 3D BIM design and detailing software for precasters, rebar retailers and civil and structural engineers.

Others include BricsCAD, Autodesk Ecotect Analysis, Microstation, Archibus, Green Building, Bentley Systems.

2.3 The Levels of BIM

According to BIM Plus, (2020), BIM is a very broad term that describes the process of creating and managing a digital model of a building or other facility such as bridge, highway, tunnel and so on. It is a collaborative way of working underpinned by digital technologies. These technologies allow for more efficient methods of designing, delivering and maintaining physical built assets throughout their entire life cycle.

Also according to (McPartland, 2014), the government of UK has recognised that the process of moving the construction industry to "full collaborative working" will be progressive, with distinct and recognisable milestones being defined within that process, in the form of "levels". They have been defined within the range from 0 – 3, and whilst there is some debate about the exact meaning of each level, the broad concept is as follows:

i. **Level 0**: describes unmanaged CAD (Computer Aided Design). This is likely to be 2D, with information being shared by traditional paper drawings, or in some instances, digitally via PDF, essentially separate sources of information covering basic asset information (bimblus.co.uk). Level 0 in its simplest form means no collaboration. 2D CAD drafting only is utilised, mainly for production information (RIBA Plan of Work, 2013 stage 4). Output and distribution is via paper and electronic prints, or a mixture of both. Majority of the industry is already well ahead of this now (NBS, 2017).

ii. **Level 1**: Involves managed CAD in 2D or 3D, it is a mix of 2D and 3D information using BS 1192 with a collaboration tool providing a Common

Data Environment (CDE), (Mordue, 2019). Also according to (McPartland, 2014), BIM level 1 typically comprises a mixture of 3D CAD for concept work, and 2D for drafting of statutory approval documentation and production information. CAD standards are managed to BS 1192:2007 and electronic sharing of data is carried out from a CDE often managed by the contractor.

To achieve level 1 BIM, the Scottish Future Trust (SFT, 2012) states you should achieve the following:

a) Roles and responsibilities should be agreed upon
b) Naming conventions should be adopted
c) Arrangement should be put in place to create and maintain the project specific codes and project spatial coordination
d) A CDE for project or Electronic Document Management System (EDMS) should be adopted to allow information be shared between all members of the project team.
e) A suitable information hierarchy should be agreed which supports the concepts of the CDE and the document repository.

iii. **Level 2**: According to McPartland, (2014), the concept of BIM levels and BIM level 2 compliance has become the accepted definition of what criteria are required to be deemed BIM – compliant, by seeing the adoption process as the next steps in a journey that has taken the industry from the drawing board to the computer and ultimately into the digital age. This involves developing building information in a collaborative 3D environment with data attached, but created in separate descriptive models. According to BIM level

2, (2020) this level provides a one stop – shop access to the level 2 standards including PAS 1192. It is distinguished by collaborative working and requires an information exchange process which is specific to that project and coordinated between various systems and project participants (SFT, 2012).

Any CAD software that each party uses must be capable of exporting to one of the common files formats such as Industry Foundation Class (IFC) or COBie (Construction Operations Building Information Exchange). This is the method of working that has been set as a minimum target by the UK government for all work on public sector work. BIM level 2 involve a series of domain and collaborative federated model. The models consisting of both 3D geometrical and non – graphical data, are prepared by different parties during the project life cycle within the context of a common data environment. Using proprietary information exchanges between various systems, project participants will have the means necessary to provide defined and validated outputs via digital transactions in a structured and reusable form.

iv. **Level 3:** Has yet to be defined in detail, but it is thought that it will include a single, collaborative, online, project model including construction sequencing, cost and management information. The latest Government Construction Strategy (GCS) by the UK government published in March, 2016 seeks to embed BIM level 2 across departments which will in turn enable departments to gradually move to BIM level 3 according to (BIM Plus, 2020).

It also said while the industry currently gets to grips with Level 2, it may be seen as a bit premature to start talking about Level 3. However, the current Level 2 strategy has been 5 years in the making and much preparation and planning required. While Level 3 is unlikely to happen in the next ten years, the wedge diagram below highlights that is likely to be an “integrated” solution around open standards such as IFC with everyone working from a single model stored somewhere in the web service or cloud.

The jump from Level 2 – 3 is a big step to take, which is acknowledged in the digital built strategy by defining four distinct delivery phase scales:

a) Level 3A: Enabling improvements in the level 2 model
b) Level 3B: Enabling new technologies and systems
c) Levels 3C: Enabling the development of new business models
d) Levels 3D: Capitalising on world leadership.

The Level 3 strategy is very much an aspirational and visionary document, with the exact details to be developed in due course.

The UK maturity model was developed by Mark Bew and Mervyn Richards. For anyone new to BIM, it can be easy to get your 2D, 3D, 4D, and 5D mixed up with your BIM levels 0, 1, 2 and 3. But by defining levels of maturity, organisations can set a benchmark as to where they currently are.

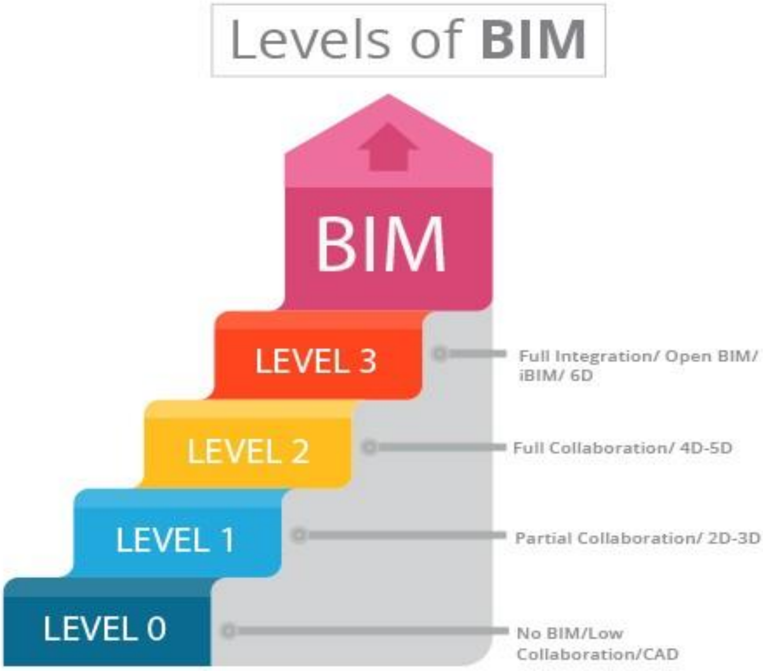

Figure 2.4: The Various Levels of BIM

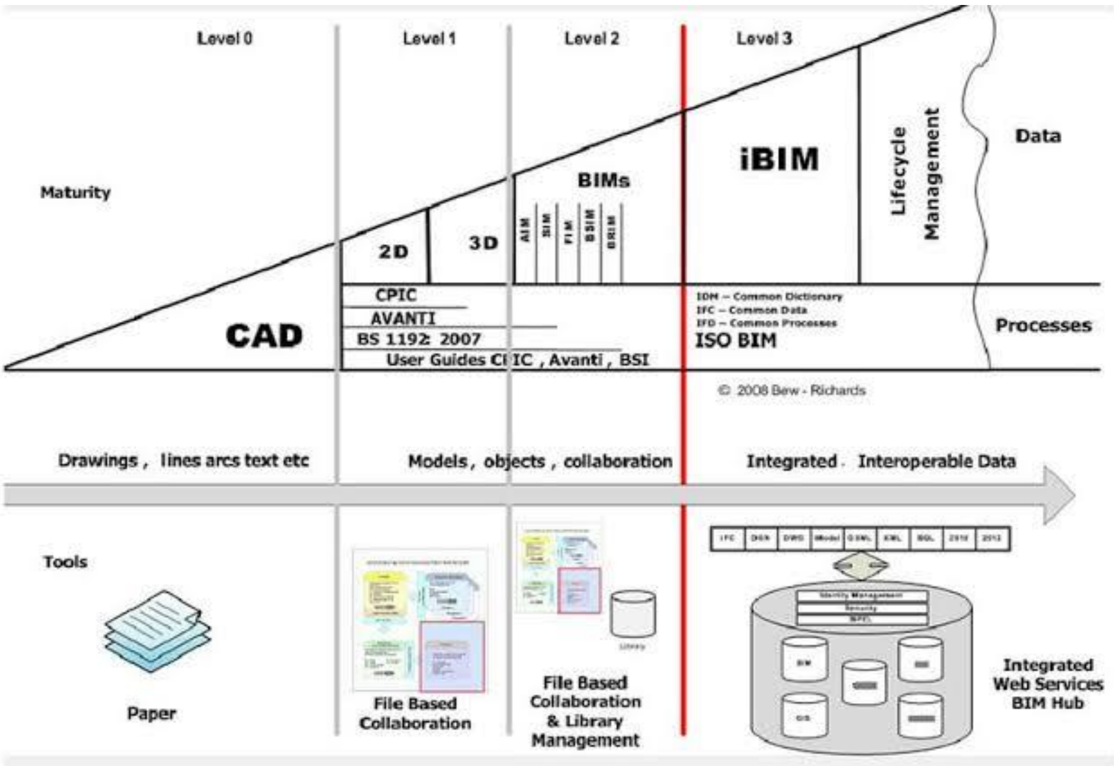

Figure 2.5:BIMMaturityLevel

According to the National Institute of Building Technology, Nashik (NIBT, 2018), Figure 2.4 presents the current levels of BIM from level 0 to level 3. Figure 2.5 presents the maturity levels of BIM technologies, a maturity scheme which is an indispensable component for understanding the ambitious approach to the opportunities opening to construction in the digital age that has come (Komosko *et al*., 2017)

What this means in practice is that the significance of these steps in real terms is that UK government for example has adopted this definition in its construction strategy, requiring that all publicly funded construction work must be undertaken using BIM to level 2 by 2016. This mandate was set as a measure to help in fulfilling their target of reducing waste in construction by 20%. It was considered that abortive work, discrepancies and mistakes and inefficiencies in the information supply chain are major contributors to this waste; and that collaborative working can assist in their reduction. And it is probable that collaborative working practice will ultimately filter through to the private sector, in much same way.

2.4 BIM and the Construction Industry

Over the years, the issue of BIM has attained widespread popularity among all stakeholders in the construction industry the world over. BIM is seen as a driver for the building industry to improve its productivity by ensuring effective communication and collaboration between all project stakeholders from inception to completion of building projects, (Ibrahim *et al*., 2014). They added that many design and construction organizations in different parts of the world are moving towards BIM adoption in their practices (Haron, *et al*., 2010).

The BIM mandate was implemented in April, 2016 according to the (NBR, 2017). According to this report:

a) 51% of respondents think the government of UK is on the right track with BIM and awareness is near universal and adoption is up (62% of practices use BIM on some projects – up 8% year on year).
b) 65% said BIM can bring real benefit beyond the design stages but 72% believed clients do not understand these benefits.
c) Government of UK hopes BIM will help in delivering projects for lower cost more rapidly with fewer greenhouse emissions, and a better trade balance for construction projects.
d) 60% think BIM will help bring time efficiencies, reducing time from inception to completion.
e) 70% believe cost reduction in the design/build/maintain lifecycle will be realised.
f) Many thought the government was failing to enforce the mandate.
g) A third respondent stated they were not clear on what they had to do to comply with the BIM mandate. Some cited lack of client education limiting the effect of BIM mandate to fully reap the fullest rewards.
h) 18% said they used BIM in every project.
i) 29% said they used BIM on more than 75% of projects.
j) 55% compared to 35% back in 2012 confident in BIM
k) 90% said BIM adoption require change in workflow, practices and procedures. Learning from colleagues 75%.
l) On BIM maturity, most respondents said that level 2 was the highest level reached on a project.

m) 7% said they were at BIM level 3; 22% at level 1. The survey showed more than three organisations who have adopted BIM are at or beyond the level required by BIM mandate.

n) 41% use Autodesk Revit, 14% AutoCAD. Autodesk dominate the UK market with 66%.

2.5 BIM Adoption and Implementation

BIM advancement in the Middle East is on the rise(Gerges, 2017).United States has recorded the most significant development in construction digitalization, Australia, United Kingdom and some other developed nations are also amongst promoters of BIM process and its development. Recently, developing countries like China and Malaysia are keying into the industry's digital shift, while very little move is seen in South Africa whose development is considered higher and perhaps leader in the digital transition amongst the African countries (Hamma – Adama and Kouieder, 2018).It added that Countries have been adopting BIM at different level and with different purpose, having different experiences (in benefits), depending on adoption level and possibly their challenges earlier to the adoption. For example, McGraw Hill Construction study discloses some substantial benefits of adopting BIM by Australia and New Zealand; these include the reduction in rework, business reputation, effective management of construction time and cost as well as reduction in errors and omissions. The rationale behind BIM adoption varies from country to country; however, there are common goals amongst most of the countries. These include, improving the industry's productivity and unifying its standardizations by changing its way of working.

According to Kori and Kiviniemi(2015), countries like Finland, USA, UK, Australia, Netherlands, Singapore, Hong Kong Norway, Denmark among others have adopted BIM technologies and have experienced significant benefits in construction project delivery (Yan and Damian, 2008; Underwood and Isikdag, 2010; Nederveen *et al.*, 2010; Sebastian and Berlo, 2010). Some of the benefits of BIM technologies as claimed by its proponents are the provision of an efficient communication and data exchange system (Nederveen *et al.*, 2010), auto quantification, improved collaboration, coordination of construction documents, improved visualisation of design (Olatunji, *et al.*, 2010; Sacks *et al.*, 2010), clash detection and cost reduction (Eastman *et al*., 2011) among others.It further stressed that despite the potentials and documented benefits, not much has been reported regarding its implementation in the Nigerian AEC industry. It requires examining the prospect of the AEC industry market through its state of art and openness to the information and digital technology.

BIM concept can be traced mostly in Architectural practices than engineering practices in Nigeria. A superficial BIM practice is found to be at organizational level only and operating a model based - “BIM stage 1.” Research to adopting this innovation has received very little attention.

2.6 Benefits of BIM

According to Okereke *et al.* (2016), there are various benefits that can be derived from using BIM. These include: better coordination, synchronization and sequencing of projects, and allowing all project participants to access and interrogate project information. At an advanced level, BIM enables better clash detection. Other benefits include: ability to visualize what is to be built in a simulated environment, higher reliability of expected field conditions, allowing for opportunity to do more prefabrication of materials off site. The building design development can continue with the provision of automatic bills of material and generation of automatic shop drawings for everything from structural steel to sheet metal duct fabrication, to fire protection and piping fabrication, to electrical cabling and bus duct layouts.

It added that BIM can potentially increase the efficiency, quality and productivity of construction projects. This it can do by reducing the number of mistakes and incompatibilities, providing more accurate and up-to-date information, and by giving a more illustrative and accessible exposition of a building. BIM streamlines the design process across the company and facilitates automation of emails via knowledge database.

2.7 Factors Affecting BIM Adoption in the Nigerian Construction Industry

The introduction and adoption of any new technology such as BIM usually requires that the factors that may positively or negatively affect the adoption by the relevant stakeholders be identified and addressed for the successful take up of the innovations and subsequent benefits to be derived thereof. Numerous potential barriers and drivers for BIM adoption were documented in literature (Ibrahim *et al*., 2014). Availability of trained professionals to handle the tools, BIM Software availability and affordability, Enabling environment, Clients' interest in the use of BIM in their projects, Awareness of the technology among industry stakeholders, Cooperation and commitment of professional bodies to its Implementation, Proof of cost savings by its adoption, Cultural change among industry stakeholders, Government support through legislation, Collaborative Procurement methods (Ibrahim *et al*., 2014).

2.8 Impact of Adoption of BIM in the Nigerian Construction Industry

Previous research on this area available in various literatures suggest some impact of the adoption of BIM in the construction industry in Nigeria. BIM affords integrators increased accuracy for quantity take-offs. Metadata attached to objects allows for accurate counting and price modelling, improving the accuracy of bids and project pricing.

According to Onungwa and Uduma-Olugu, (2017), BIM is fast dictating the pace of professionals in the construction industry and changing the process of design and construction of buildings. They further quoted (Hassan and Yolles, 2009) as saying that the 3D modelling process extends to scheduling and sequencing (4D), cost estimating (5D), sustainable design also termed Green Design (6D) and facility management (7D).

2.9 Barriers to the Adoption of BIM in the Nigerian Construction Industry

According to Ibrahim *et al*.(2014), some of the barriers to adoption of BIM in the construction industry in Nigeria are: Social and habitual resistance to change, Legal and contractual constraints, High cost of training, Lack of enabling environment (Government policies and legislations), Lack of trained professionals to handle the tools, Clients not requesting the use of BIM on projects, No proof of financial benefits, High Cost of integrated software/models for all professionals, Lack of standards to guide implementation, Poor internet connectivity, frequent power failure, lack of awareness of the technology among industry stakeholders.

Also according to Ahmed and Houque (2018), the barriers include the Social and habitual resistance to change, Traditional methods of contracting, Training expenses and the learning curve are too expensive, High cost of software purchasing, Lack of awareness about BIM, High cost of BIM hardware and tools, Initial set up of BIM is difficult, Lack of BIM experts, High Maintenance costs, Unavailability of proper training on BIM, Complexity of BIM, and BIM licensing problems. Ibrahim and Abdullahi,(2016) also added the following as the barriers to the implementation of BIM in Nigeria.

2.9.1 Process barriers

i. Lack of Awareness of the technology
ii. Lack of knowledgeable and experienced partners
iii. Lack of Trained Professionals to handle the tools
iv. High Cost of Training
v. Clients are not requesting the use of BIM on projects
vi. Lack of Enabling Environment (government policies and legislations) to guide implementation
vii. No proof of financial benefits
viii. Legal and Contractual Constraints
ix. Social and Habitual Resistance to change

2.9.2 Technology barriers

i. Frequent Power Failure
ii. High Cost of Integrated software/Models for all professional
iii. Lack of Standards to Guide Implementation

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Research Design and Methods

Research design as defined by Kothari (2004) is the arrangement for collection and analysis of data in a manner that combines relevance to the research purpose with economy in procedure. The study adopted a single method approach (quantitative research design). This quantitative approach was based the use of questionnaires alone.

3.2 Research population

Research population refers to the group of entities to which the researcher intends to make an inference; such entities usually possess some unique common characteristics. The research population for the study are the professionals working in construction firms in Abuja, Federal Capital Territory and the following states comprising of Niger and Nassarawa states.

3.3 Sample frame

Sample frame simply defined consists of the list of entities from which the specific entities to be sampled are selected. In other words, the sampling frame represents the accessible section of the target population. For this study the sample frame was made up of the professionals in the study area, who could be accessed electronically through their email addresses. Although efforts were made to obtain the electronic contact addresses of as many of these professionals as possible through their professional associations, such efforts were not successful. The researcher was left with the only possible option of making direct electronic contact with likely sample elements based on personal knowledge of the subject of the study and study area.

3.4 Sample size

A sample size refers to the number of entities that are selected for the purpose of providing data in the survey (Zamboni, 2017). For the purpose of this research, a convenience sample of the professionals who could be accessed electronically was carried out. The convenience sample was built up through a snowballing approach. A total of 252 professionals were eventually sampled.

3.5 Sampling techniques

There are basically two kinds of sampling procedure, and they are: Probability and Non-probability sampling technique (Walliman, 2011). Probability sampling techniques presents the most reliable representation for the whole population, because it gives each respondent an equal chance to be captured, while non-probability techniques rely on the judgement of the researcher, thereby making generalization on the population difficult and not justifiable (Walliman, 2011). The study adopted a mix of the probability and non-probability sampling technique through the use of convenience sampling and snowball sampling. The researcher believes the use of these approaches is justified in the light of the low diffusion of BIM in the Nigerian Construction Industry.

3.6 Procedure for Data Collection

The research carried out review of existing literature first, so as to gain familiarity with the current status of research activity in the research area. A structured questionnaire was thereafter designed and administered to achieve the various research objectives.

3.7 Method of Data Analysis and Presentation

After collecting the data from the respondents via the structured questionnaire, the data gathered was analysed in relation to the stated objectives as presented in Table 3.1. The data for Objectives 1, 2and 3 was analysed using descriptive statistical method (Ranking Method based on Relative Importance Index and Mean Item Score). The analysed data was presented using tables and charts.

Table 3.1: Methods of Data Analysis

S/N	Objectives	Data Tools	Analysis Instrument
1	To ascertain in general terms the level of BIM in operation in the Nigeria Construction Industry	Literature review, Questionnaire	Mean Score, Relative Importance Index
2	To determine the impact of the level of BIM adoption in the project life cycle of construction projects	Questionnaire	Mean Score, Relative Importance Index
3	To ascertain the existence of government construction strategy for the adoption and implementation of BIM in the Nigerian construction industry	Questionnaire	Mean Score, Relative Importance Index

Source: Author (2020)

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results of Demographic Analysis of Respondents

The demographic spread of respondents is presented in pie-charts labelled as Figure4.1 to Figure 4.4. Quantity surveyors were the most numerous of the professionals sampled, comprising 56% of the sample. Other major subgroups of professionals included architects (19% of the sample), builders (7%), engineers (6%) and project managers (4%). The implications of the spread of the professions of respondents in this study include the probability of the views of quantity surveyors dominating that of other professionals. It also shows that key professions in the actual building construction process were covered in the survey. This result is presented in Figure 4.1.

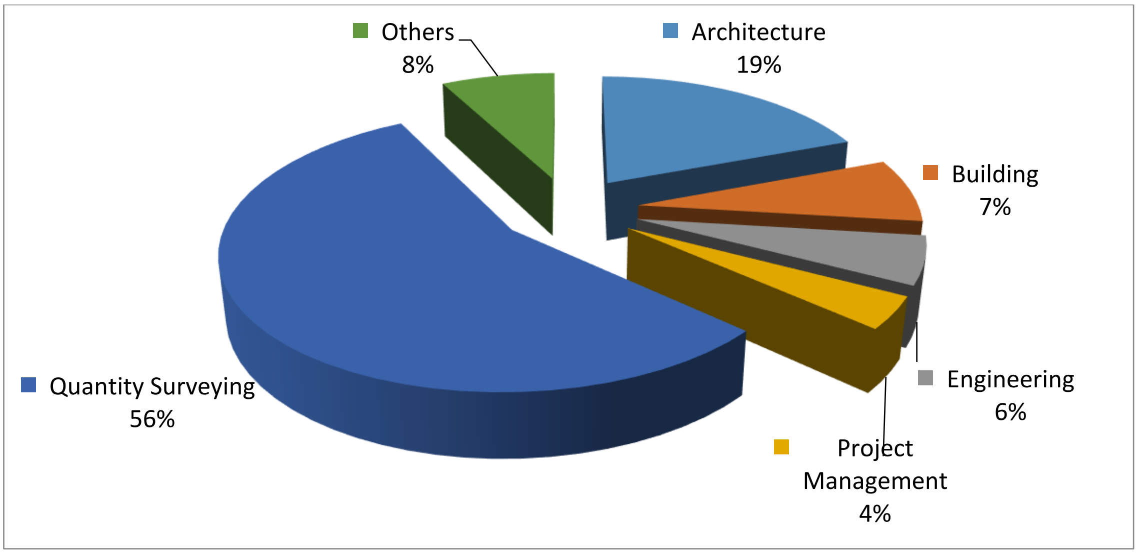

Figure 4.1: Respondents' professional area

The result in Figure 4.2 was for the type of organisation that respondents worked for. A third of the sample (33%) worked for contractors; a further 34% worked for consultants, while only 10% of the sample worked for public sector agencies. Respondents whose employer status fell outside of the three categories mentioned here were grouped into one broad category labelled ‘Others’. The spread of the sample across different employers helped the study to collate the views and experiences of key participants in the Nigerian Construction Industry (NCI).

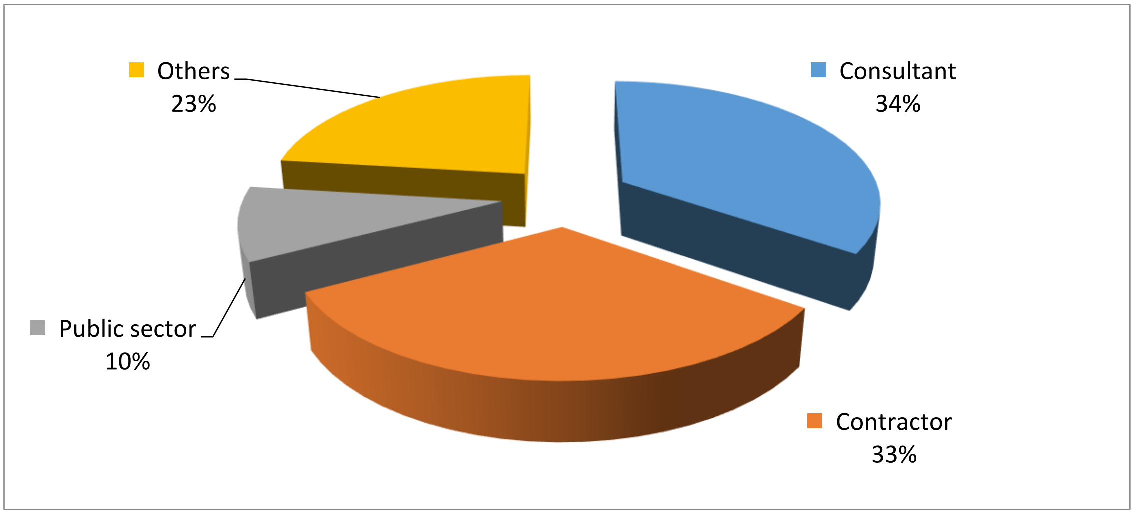

Figure. 4.2: Type of organisation

Building Information Modelling (BIM) was developed outside Nigeria; for this reason, the scale of operations of entities in the NCI will have an effect on the adoption and use of BIM technologies. Construction firms that have an international presence are more likely to be exposed to BIM earlier. For this reason, the scale of operation of the employers that the respondents worked for was examined. The result is presented in Figure 4.3.

It was found that close to two-thirds of the sample (63%) worked for employers that had only a local presence in Nigeria alone. A third of the respondents worked for employers that combined international with local presence in Nigeria. Respondents who did not provide responses that could be suitable classified made up the balance of 4%. This study thus draws inferences on the adoption of BIM in the NCI from both local and multinational firms.

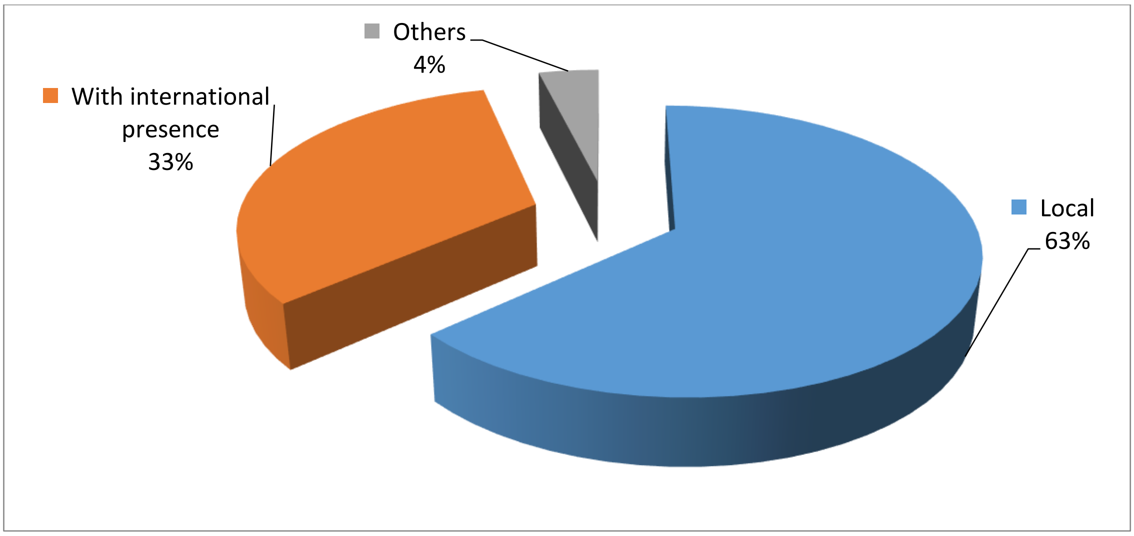

Figure 4.3: Scale of respondents' organization

The final pie-chart which is labelled Figure 4.4 provided information relating to the extent of experience acquired by the respondents. There were no respondents who had worked for less than 2 years; those who had worked for between 2 and 5 years comprised 29% of the sample.

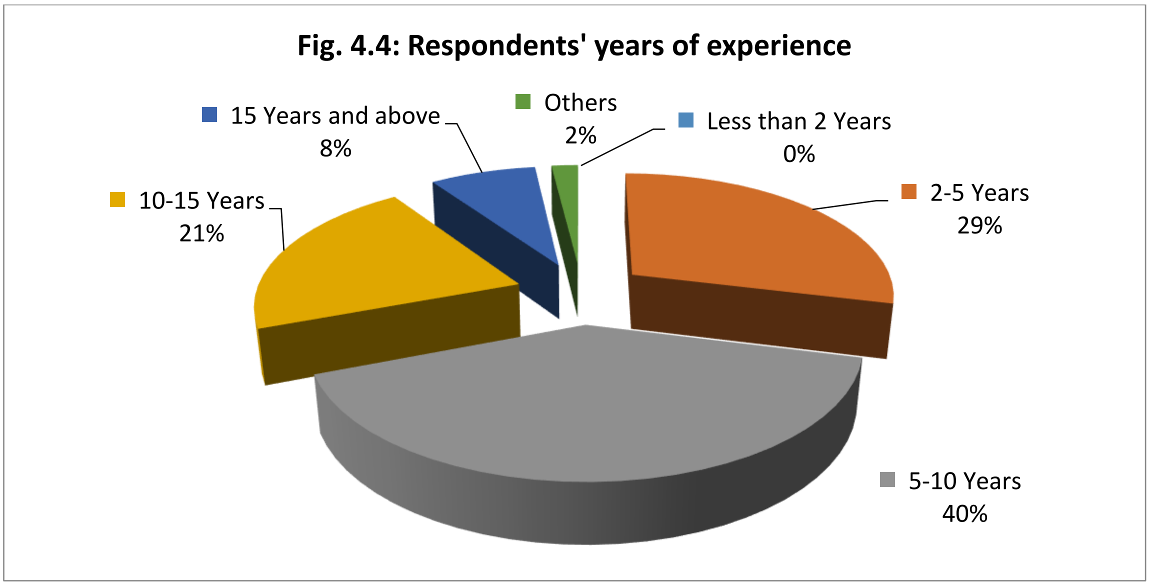

Figure 4.4: Respondents' years of experience

A further 40% of the sample had worked for between 5 and 10 years; respondents who had acquired between 10 and 15 years' experience made up 21% of the sample. Very experienced professionals, possessing more than 15 years of work experience, comprised 8% of the sample. From these results it was apparent that the respondents were professionals who had worked for sufficiently long enough to have experienced the use of BIM if it had been adopted in the organizations.

4.2 General Level of BIM in Operation in the Nigeria Construction Industry

This second section of the chapter focuses on the analysis of data carried out towards meeting the first Objective of the study, which was ‘To ascertain in general terms the level of BIM in operation in the Nigeria Construction Industry’. Mean score analysis, standard deviation and relative importance index were employed in ranking the various aspects of the use of BIM in the NCI. The results were reported in tabular form.

4.2.1 Level of BIM in area of practice

BIM use was presented in terms of the different phases that the use of a new technology passes through. These are awareness, acceptance, adoption, implementation and investment. The results of the analysis revealed that within the sample of professionals taken from the NCI, BIM awareness and acceptance are at medium levels; this was inferred from Mean Score values of 3.10 and 2.70, which lay within the ‘Medium’ range (2.50 to 3.49). BIM adoption, implementation and investing in BIM are however at low levels, given observed Mean Score values ranging from 2.08 to 2.38.

Table 4.1: Level of BIM in area of Practice

level of BIM in area of practice	Mean Score	SD	RII	Rank	BIM Level
Awareness	3.10	1.52	0.49	1	Medium
Acceptance	2.70	1.52	0.43	2	Medium
Adoption	2.38	1.43	0.38	3	Low
Implementation	2.30	1.53	0.37	4	Low
Investing in BIM	2.08	1.52	0.33	5	Low

This implies that a lot still has to be done in the areas of awareness and adoption, in order to improve the uptake of BIM technology. This needs to be done before efforts can be directed towards improving the adoption, implementation and investing in BIM. These results align with those of (Hamma-Adama and Kouieder, 2018) that very little movement in BIM matters is visible in South Africa whose development is considered higher and perhaps a leader in the digital transition amongst the African countries.

4.2.2 BIM software package(s) most commonly used

The use of BIM software packages was presented in this result. A total of seven different BIM software packages were examined in terms of frequency of use. Respondents opined that only one package, AutoCAD, was most commonly used, being subject to a ‘High’ frequency of use. Software packages that could be described as having a ‘Medium’ frequency of use included Revit and ArchiCAD. SketchUp, another package was found to be of ‘Low’ frequency of use. The rest three packages, Bentley, Tekla structure, and Navis Works were subject to ‘Very low’ frequency of use.

Table 4.2: Frequency of use of BIM software packages

BIM software package(s) mostly used	Mean Score	SD	RII	Rank	Remark
Revit	2.73	1.73	0.38	2	Medium
AutoCad	3.83	1.23	0.59	1	High
Sketchup	1.95	1.66	0.26	4	Low
ArchiCad	2.67	1.76	0.36	3	Medium
Bentley	0.84	1.22	0.10	8	Very low
Tekla structure	0.97	1.46	0.11	7	Very low
Navis Works	1.30	1.54	0.17	6	Very low
Others	1.93	2.02	0.17	5	Low

Based on the results presented in Table 4.2, the most commonly used BIM software packages in the NCI, in order of use, are AutoCAD, Revit and ArchiCAD. In the UK, 41% of professionals in the construction industry use Autodesk Revit, while 14% AutoCAD (National BIM report, 2017).

4.2.3 Knowledge of the various levels of BIM

This result presented the knowledge possessed by respondents regarding the four levels of BIM. BIM level 0 refers to a situation where NCI professionals employ 'Hand drawing alongside 2D CAD drafting'. It is the lowest BIM level, and usually indicative of very low uptake of BIM technology. BIM level 1 is associated with 'A mixture of 3D CAD for concept work and 2D CAD for drafting of statutory approval, documentation and production information'. At level 1 the full functionality of BIM is severely limited, since production information still uses 2D CAD. BIM level 2 employs 3D models based on a database containing all required information as well as parametric modelling'. This is a very high level of BIM technology, since it allows the realisation of services such as Computer-Assisted Facilities Management.

The results obtained showed that respondents had a 'Medium' level of knowledge about BIM level 0and BIM level 1. The corresponding level of knowledge for BIM level 2 and BIM level 3 was 'Low'. This agrees with the position by (Kori and Kiviniemi, 2015) that the NCI is still mostly at BIM Level 1.

Table 4.3: Respondents' knowledge of the various levels of BIM

knowledge of the various levels of BIM	Mean Score	SD	RII	Rank	Remark
BIM Level 0	2.75	1.42	0.42	1	Medium
BIM Level 1	2.55	1.39	0.40	2	Medium
BIM Level 2	2.28	1.37	0.37	4	Low
BIM Level 3	2.30	1.45	0.37	3	Low

4.2.4 Level of BIM organisations are operating

Having examined the extent of knowledge possessed by respondents about the different BIM levels, this result presented the extent to which organizations within the NCI operate the different levels of BIM. The results revealed a 'Low' level of operation of all of the four levels of BIM.

These findings are somewhat puzzling, because they imply that even the manual, 2D-based operations associated with BIM level 0 are also carried out at a low level within the NCI. However, the results do provide some insight into the abysmally low operation of BIM in the NCI.

Table 4.4: Level of BIM operated by organisation in the NCI

Level of BIM organisation is operating?	Mean Score	SD	RII	Rank	Remark
BIM Level 0	1.98	1.52	0.26	2	Low
BIM Level 1	2.17	1.48	0.29	1	Low
BIM Level 2	1.88	1.56	0.26	3	Low
BIM Level 3	1.80	1.61	0.25	4	Low
Not sure	1.51	1.56	0.17	5	Low

4.2.5 Organisation's BIM implementation strategy

Here, the study presented the various approaches employed in the NCI towards the implementation of BIM strategies. The result of the examination is presented in Table 4.5, and revealed that the use of selected teams in the implementation of BIM strategy has been employedto a 'Medium' extent (Mean Score was 2.53). all other approaches such as 'Top down', '|Bottom up' and 'Using multiple teams' were employed to a 'Low' extentonly. Within the group of six strategies that fell within the 'Low' category, it was observed that 'using BIM on all projects' ranked ahead of other strategies.

Table 4.5: BIM Implementation strategy adopted by organisation in the NCI

organisation's BIM implementation strategy	Mean Score	SD	RII	Rank	Remark
Top down	2.30	1.69	0.24	4	Low
Bottom up	2.35	1.69	0.26	3	Low
Using selected teams	2.53	1.61	0.31	1	Medium
Using multiple teams	1.92	1.52	0.22	7	Low
Only on specific projects	2.17	1.53	0.29	5	Low
All projects	2.39	1.76	0.29	2	Low
Entire organisation	2.03	1.73	0.23	6	Low
None	0.88	1.28	0.07	8	Very low

4.2.6 BIM tools that construction organisations currently employ for projects execution

The BIM tools that organizations in the NCI employ in the construction of projects were examined here, and the result was presented in Table 4.6. BIM is practiced mainly through distribution of contract or production information 'via paper or electronic form e.g. PDF'; this was ranked 1st, and had a Mean Score of 3.85. Ranked 2nd and 3rd were use of '2D CAD for drafting of statutory approvals, documentation and production information', and the mixing of '3D CAD for concept work'. All of these three approaches were employed to a 'High' extent.

Organizations also practiced BIM to a ‘Medium’ extent through ‘2D CAD drafting’ (Mean Score 3.47, ranked 4th), ‘Sharing data from a Common Data Environment (CDE)’ (Mean Score 2.76, ranked 5th), and ‘common BIM file formats such as Industry Foundation Class (IFC) or Construction Operations Building Information Exchange (COBie)’ (Mean Score 2.59, ranked 6th).

The use of ‘Hand drawing’ (Mean score 1.94, ranked 8th) has all but faded out in the NCI, since it was found to be employed to a ‘Low’ extent only. At the other end of the spectrum, the use of ‘A collaborative 3D BIM (with all projects and asset information, documentation and data being electronic)’ (Mean score 2.43, ranked 7th) still appears to be a far cry from being achieved, since at present it was only being employed to a low extent.

Table 4.6: BIM tools employed by organisation in the NCI

BIM tools organisation currently employs for projects execution	Mean Score	SD	RII	Rank	Remark
Hand drawing	1.94	2.11	0.21	8	Low
2D CAD drafting	3.47	1.56	0.50	4	Medium
Distribution via paper or electronic form e.g. PDF	3.85	1.40	0.57	1	High
A mixture of 3D CAD for concept work	3.60	1.42	0.50	3	High
2D CAD for drafting of statutory approvals, documentation and production information	3.63	1.36	0.48	2	High
Sharing data from a Common Data Environment (CDE)	2.76	1.82	0.34	5	Medium
A collaborative 3D BIM (with all projects and asset information, documentation and data being electronic)	2.43	1.62	0.31	7	Low
Using a CAD software that all parties use and capable of exporting to one of the common BIM file formats such as Industry Foundation Class(IFC) or Construction Operations Building Information Exchange(COBie)	2.59	1.80	0.34	6	Medium

4.2.7 Does BIM have a bright future in the Nigerian construction industry?

Respondents were also asked about their perception of the likelihood that BIM has the potential to do extremely well in the NCI in the near future. On the whole, the entire sample agreed that BIM has a bright future in the NCI (Mean Score 4.24).

Table 4.7: Future of BIM in the NCI

Respondent category	Mean Score	SD	RII	Rank	Remark
All	4.24	1.25	0.68		Agree
Consultant	4.56	0.70	0.76	1	Strongly agree
Contractor	4.44	0.89	0.70	2	Agree
Government	3.40	2.19	0.57	3	Neutral

Within the sample, respondents who worked for Consultants were most optimistic, since they agreed strongly with this view. Respondents who worked for public sector agencies however maintained a 'Neutral' position, figuratively preferring to 'sit on the fence'. This position might indicate scepticism on the part of the public sector agencies; this situation is worrisome, since these are the agencies that will need to serve as facilitators for the use of BIM to take root in the NCI. However, when the different barriers that confront the adoption of BIM in the NCI are considered as outlined by (Ibrahim *et al*., 2014), this scepticism might be understandable.

4.2.8 Number of projects involved with in the last ten years

An interesting finding of the study was that, based on the possibility that organizations operated at only BIM Level 0 or BIM Level 1, about two-thirds of all projects carried out by the organizations that the respondents worked for in the NCI utilised BIM. This however applied only to projects executed in the last 10 years. While the fact that organizations have not progressed beyond BIM Level 1 is enough cause for worry, it appears likely that with appropriate strategies and incentives, organizations in the NCI can be guided to a rapid uptake of BIM technology.

Table 4.8: BIM projects in the last ten years

Respondent category	How many projects have your organisation been involved with in the last ten years?		How many of these projects adopted BIM at any stage of execution?	
	Mean Score	**Range of projects handled**	**Mean Score**	**Range of projects handled with BIM**
All	3.12	11 to 15 projects	1.90	6 to 10 projects
Consultant	3.17	11 to 15 projects	1.76	6 to 10 projects
Contractor	3.12	11 to 15 projects	1.88	6 to 10 projects
Government	2.80	11 to 15 projects	2.20	6 to 10 projects

4.2.9 Project life cycle stage where BIM was adopted

Analysis of the research survey data revealed that BIM is mostly applied in the 'Design' stage of construction projects (Mean Score 3.50, ranked 1st), as presented in Table 4.9. Other project lifecycle stages that are 'Medium' users of BIM include 'Detailing' and 'Budget and estimates' (Mean Scores 3.19 and 2.88, ranked 2nd and 3rd respectively). 'Medium' use is also made of BIM during the 'Project management', 'Planning', and 'Delivery' stages of projects.

However, it was found that the 'Fabrication' stage of projects involves the least use of BIM (Mean Score 2.27, ranked 8th). This is understandable in the light of the extremely low diffusion of any technology beyond BIM Level 1. BIM technologies higher than BIM Level 1 make use of object-oriented databases, which make it possible to automate the fabrication of component parts of construction projects. This is an area in which the NCI is still lagging behind; it is in this area that countries like Finland, USA, UK, Australia, Netherlands and Singapore have experienced significant benefits in construction project delivery (Kori and Kiviniemi, 2015) through the use of BIM Level 2 and 3.

Table 4.9: BIM in projects life cycle

Project life cycle stage where BIM was adopted	Mean Score	SD	RII	Rank	Remark
Planning	2.61	1.73	0.38	5	Medium
Design	3.50	1.65	0.54	1	High
Detailing	3.19	1.85	0.48	2	Medium
Fabrication	2.27	1.68	0.32	8	Low
Construction	2.59	1.81	0.38	6	Medium
Budget and estimates	2.88	1.73	0.44	3	Medium
Project management	2.67	1.74	0.41	4	Medium
Delivery	2.53	1.88	0.37	7	Medium
Others	1.96	1.82	0.16	9	Low

Further analysis of the data according to the three main groups of employers that respondents worked for (consultants, contractors and government) revealed that emphasis on the use of BIM varied amongst the groups. Respondents who worked for Consultants believed that the 'Detailing' stage of projects is the heaviest user of BIM, as opposed to the view of respondents within the Contractor and Government groups, that the 'Design' stage used BIM the most. Respondents within all three groups were however agreed that the 'Fabrication' stage of projects used BIM the least. These results are presented in Table 4.10.

Table 4.10: Use of BIM in projects life cycle

Project life cycle stage where BIM was adopted	Consultants			Contractors			Government		
	Mean Score	SD	Rank	Mean Score	SD	Rank	Mean Score	SD	Rank
Planning	2.53	1.74	4	3.21	1.05	4	1.40	2.19	9
Design	3.41	1.80	2	3.93	1.22	1	2.80	2.17	1
Detailing	3.41	1.84	1	3.50	1.22	2	2.00	2.74	4
Fabrication	2.00	1.59	8	2.46	1.20	8	2.00	2.74	8
Construction	2.22	1.66	7	3.00	1.41	7	2.00	2.74	7
Budget and estimates	2.61	1.75	3	3.47	1.41	3	2.40	2.51	3
Project management	2.47	1.77	5	3.13	1.41	6	2.00	2.74	6
Delivery	2.24	1.75	6	3.17	1.47	5	2.00	2.74	5
Others	1.91	1.87	9	1.29	1.60	9	2.50	3.54	2

4.2.10 Organisational adoption of BIM in project execution

All respondents were asked whether their organisation has fully adopted BIM in the execution of their projects. Only respondents who worked for the government agreed with this position. Respondents who worked for Consultants and Contractors preferred to remain ‘Neutral’. This result as presented in Table 4.11 suggests that a good proportion of construction professionals realise that BIM technologies have not yet been fully deployed on projects in the NCI. This position also aligns with the earlier finding in Subsection 4.2.7 where respondents agreed that BIM has a bright future in the NCI.

Table 4.11: Adoption of BIM in project execution

Survey Question	Respondent category	Mean Score	SD	RII	Rank	Remark
Organisation has fully adopted BIM in project execution?	All	3.18	1.40	0.45		Neutral
	Consultant	3.20	1.08	0.44	3	Neutral
	Contractor	3.31	1.38	0.42	2	Neutral
	Government	3.60	1.95	0.60	1	Agree

4.3 Impact of BIM Adoption Levelsin Construction Projects

This third section of the chapter focuses on the analysis of data carried out towards meeting the second Objective of the study, which was ‘To determine the impact of the level of BIM adoption in the project life cycle of construction projects’. Mean score analysis, standard deviation and relative importance index were employed in ranking the various aspects of the use of BIM in the NCI. The results were reported in tabular form.

4.3.1 Influence of BIM adoption on projects

Respondents were asked to indicate the extent to which BIM has influenced their projects in different aspects of improvement. The results are presented in Table 4.12; projects performance in several key performance areas was computed before and after adoption of BIM. Project performance pre-BIM was then compared with that of the post-BIM period, in order to show whether any significant change could be observed.

The results revealed that in four out of the eight aspects of project performance that were reviewed, BIM adoption appeared to have had a noticeable impact. These four aspects were 'Greater control of the construction process' (Mean Score 2.89, ranked 1st); 'Improved collaboration between agents' (Mean Score 2.87, ranked 2nd); 'Conflict resolution and clash detection' (Mean Score 2.63, ranked 7th); and 'Reduction in labour' (Mean Score 2.47, ranked 8th). All rankings refer to post-BIM performance. This meant that whereas in the pre-BIM period, performance in terms of control, collaboration, conflict resolution and labour reduction had been 'Low', the adoption of BIM had improved performance up to the 'Medium' extent range. These findings agree with those of previous studies such as (Nederveen *et al.,*2010) that benefits of BIM technologies include the provision of an efficient communication and data exchange system.

Table 4.12: Influence of BIM Adoption on projects

Influence of BIM adoption on projects	**Pre-BIM**			**Post-BIM**			**Remark**
How has BIM influenced your projects in terms of the following?	**Mean Score**	**Rank**	**Level**	**Mean Score**	**Rank**	**Level**	
Waste reduction	2.74	1	Medium	2.85	3	Medium	Unchanged
Reduction in labour	**2.70**	**4**	**Medium**	**2.47**	**8**	**Low**	**Changed**
Reduction in deviations	2.73	2	Medium	2.80	4	Medium	Unchanged
Reduction in variations/claims	2.70	3	Medium	2.67	6	Medium	Unchanged
Greater control of the construction process	**2.41**	**6**	**Low**	**2.89**	**1**	**Medium**	**Changed**
Improved collaboration between agents	**2.24**	**8**	**Low**	**2.87**	**2**	**Medium**	**Changed**
Conflict resolution and clash detection	**2.30**	**7**	**Low**	**2.63**	**7**	**Medium**	**Changed**
Correction and error finding	2.66	5	Medium	2.70	5	Medium	Unchanged

4.3.2 Influence of BIM adoption on design of construction projects

This section dealt with how the adoption of BIM has influenced the design of projects. Respondents were asked to indicate the extent to which BIM has influenced the design of their projects. The results are presented in Table 4.13; project design performance in several key performance areas was computed before and after adoption of BIM. Design performance pre-BIM was then compared with that of the post-BIM period, in order to show whether any significant change could be observed.

The result showed that the design performance of projects improved in only 1 out of 8 aspects. This was 'Improved conflict resolution' (Mean Score 2.69, ranked 7th). In all of the rest seven aspects, there was no significant change in the design performance of projects. Previous researches have however found that BIM adoption could result in benefits such as auto quantification, improved collaboration, coordination of construction documents, improved visualisation of design (Olatunji *et al.*, 2010).

Table 4.13: Influence of BIM Adoption on project design

Influence of BIM adoption on design	**Pre-BIM**			**Post-BIM**			**Remark**
How has BIM influenced your project designs in terms of the following?	**Mean Score**	**Rank**	**Level**	**Mean Score**	**Rank**	**Level**	
Improved quality	2.79	3	Medium	3.15	2	Medium	Unchanged
Increased speed	2.67	4	Medium	3.02	4	Medium	Unchanged
Reduction in cost	2.87	1	Medium	2.76	5	Medium	Unchanged
Greater amount of data/information available	2.64	6	Medium	3.02	3	Medium	Unchanged
Less rework	2.65	5	Medium	2.69	8	Medium	Unchanged
Improved conflict resolution	**2.47**	**8**	**Low**	**2.69**	**7**	**Medium**	**Changed**
More effective communication	2.54	7	Medium	2.74	6	Medium	Unchanged
Higher level of accuracy	2.79	2	Medium	3.20	1	Medium	Unchanged

4.3.3 Influence of BIM adoption on building elements

In this subsection the influence that the adoption of BIM has had on elements of building projects was examined. Respondents were asked to indicate the extent to which BIM has contributed to the improvement of the elements of their building projects. The results are presented in Table 4.14;Eight (8)building elements were involved. Elements were then ranked in terms of their Mean Scores, in order to show which element has been most influenced by BIM adoption.

Table 4.14: Influence of BIM Adoption on building elements

What elements of your projects are produced in 3D digital descriptions/representations, inserting graphical objects with their functional characteristics and properties?	Mean Score	SD	RII	Rank	Remark
None	1.68	1.87	0.15	10	Low
Walls	3.18	1.83	0.39	4	Medium
Doors	3.32	1.72	0.39	1	Medium
Windows	3.19	1.78	0.38	3	Medium
Roof	3.24	1.79	0.38	2	Medium
Electrical installation	2.50	1.66	0.29	9	Medium
Mechanical installation	2.69	1.60	0.31	5	Medium
Reinforcements	2.66	1.78	0.30	7	Medium
Plumbing	2.69	1.68	0.30	6	Medium
Others	2.52	2.04	0.17	8	Medium

The results obtained revealed that BIM adoption has had ‘Medium’ impact on all eight building elements. Although the ranking based on Mean Scores identified the most impacted elements as Doors, Roof, Windows and Walls, it was observed that the Mean Scores for the ranked elements all fell within the ‘Medium’ range of the semantic scale employed in the research questionnaire.

The results in Table 4.15 represent an attempt to check whether respondents’ perception of the influence of BIM adoption varied according to the type of employer the respondents worked for.It was observed that respondents in the Consultant group ranked Doors, Windows and Roof as elements most impacted by BIM adoption.

Table 4.15: Influence of BIM Adoption on building elements

Influence of BIM adoption on Building Elements	Consultant			Contractor			Government		
What elements of your projects are produced in 3D digital representations?	**Mean Score**	**SD**	**Rank**	**Mean Score**	**SD**	**Rank**	**Mean Score**	**SD**	**Rank**
None	0.75	1.39	10	2.56	2.13	10	0.67	1.15	9
Walls	2.85	1.99	4	3.92	1.56	2	2.00	2.45	1
Doors	3.17	1.99	1	3.85	1.41	3	2.00	2.45	1
Windows	3.00	2.05	2	3.85	1.41	4	2.00	2.45	1
Roof	3.00	2.00	3	3.92	1.50	1	2.00	2.45	1
Electrical installation	1.91	1.92	9	3.33	1.37	7	1.00	1.41	5
Mechanical installation	2.64	1.96	5	3.25	1.36	8	1.00	1.41	5
Reinforcements	2.09	2.07	8	3.50	1.57	5	1.00	1.41	5
Plumbing	2.36	2.11	6	3.42	1.16	6	1.00	1.41	5
Others	2.17	2.32	7	3.13	2.10	9	0.00	0.00	10

Roof, Walls and Doors were selected as the elements most impacted by BIM adoption by respondents in the Contractor group. Rankings by the respondents in the Government group were inconclusive, probably owing to its smaller data set. This result showed that there was little variation in the perceptions of the respondents based on the type of employer.

4.3.4 Level of BIM use on projects

The study also attempted to gauge the level of use of BIM on construction projects that the respondents had been involved with. Respondents were provided with a list of different tasks that are usually carried out on projects and asked to rank the extent to which they had used BIM in executing the tasks. The results are presented in Table 4.16.

Table 4.16: BIM use on projects

What is the current level of the following parameters on your projects?	Mean Score	SD	RII	Rank	Remark
Manual drafting and paper representations	1.90	1.61	0.25	10	Low
CAD software for design and documentation	**3.58**	**1.48**	**0.49**	**4**	**High**
Drawings in 2D/3D (2D for design drawings and 3D models) of the project elements and structural drawings	**3.80**	**1.57**	**0.50**	**2**	**High**
Sections and cross sections	**3.73**	**1.48**	**0.48**	**3**	**High**
Elevation views	**3.83**	**1.43**	**0.49**	**1**	**High**
Dimensions and reinforcements drawings	3.46	1.55	0.46	5	Medium
Detailed design of steel connections	3.41	1.56	0.45	6	Medium
Digital descriptions of every aspect of the physical project	3.17	1.58	0.42	7	Medium
Inserting graphical objects with their functional characteristics and properties	2.86	1.73	0.38	8	Medium
Design that provide useful data for collecting cost, thermal/energy performance, aspects, maintenance, structural calculations, technical installation, facility management, health and safety maintenance, technology system design	2.64	1.61	0.36	9	Medium

'High' level of BIM use on projects was observed in the case of four tasks; these were (i) Elevation views (Mean Score 3.83, ranked 1st), (ii) Drawings in 2D/3D (2D for design drawings and 3D models) of the project elements and structural drawings (Mean Score 3.80, ranked 2nd), (iii) Sections and cross sections (Mean Score 3.73, ranked 3rd), and (iv) CAD software for design and documentation (Mean Score 3.58, ranked 4th). Of the rest five tasks that were left, four were associated with 'Medium' level use of BIM, while 'Manual drafting and paper representations' was associated with a 'Low' level of BIM use (Mean Score 1.90, ranked 10th). It was clear that as claimed by (Onungwa and Uduma-Olugu, 2017), BIM is fast dictating the pace of professionals in the construction industry.

The results in Table 4.17 show that respondents who worked for consultants, contractors and government did not differ widely in the use they made of BIM on their projects. Respondents who were employed by consultants used BIM mostly for Sections and cross sections, Elevation views and Drawings in 2D/3D. Respondents employed by Contractors and Government on the other hand used BIM mostly for Elevation views, CAD software for design and documentation, and Drawings in 2D/3D.

Table 4.17: BIM use according to BIM levels

What is the current level of the following parameters on your projects?	Consultant			Contractor			Government		
	Mean Score	SD	Rank	Mean Score	SD	Rank	Mean Score	SD	Rank
Manual drafting and paper representations	1.64	1.65	10	1.92	1.61	10	0.75	1.50	10
CAD software for design and documentation	3.67	1.29	6	3.43	1.70	2	4.75	0.50	2
Drawings in 2D/3D (2D for design drawings and 3D models) of the project elements and structural drawings	4.08	1.12	3	3.40	2.10	3	4.75	0.50	3
Sections and cross sections	4.38	0.65	1	3.20	1.82	4	4.67	0.58	4
Elevation views	4.21	0.89	2	3.46	1.81	1	5.00	0.00	1
Dimensions and reinforcements drawings	3.79	1.12	5	3.14	2.03	5	4.50	0.58	5
Detailed design of steel connections	3.86	1.23	4	2.86	1.92	9	4.25	0.96	6
Digital descriptions of every aspect of the physical project	3.36	1.50	7	2.93	1.94	8	3.75	0.96	7
Inserting graphical objects with their functional characteristics and properties	2.67	1.80	8	2.93	2.06	7	3.00	1.63	8
Design that provide useful data for collecting cost, thermal/energy performance, aspects, maintenance, structural calculations, technical installation, facility management, health and safety maintenance, technology system design	2.19	1.52	9	3.00	1.87	6	2.75	2.06	9

4.3.5 Current BIM practices in execution of projects

This subsection examined the current BIM practices in the execution of projects by respondents. A total of 14 practices were ranked by respondents with the aid of a semantic scale, and the results are presented in Table 4.18. Only one (1) practice was ranked as occurring to a 'High' extent; this was 'CAD files (2D and 3D) are primarily used' (Mean Score 3.69, ranked 1st). Ten (10) other practices were carried out to a 'Medium' extent; examples include 'Construction site is provided with the traditional paper version of the documentation'; 'Construction sites are provided with the traditional paper version of all documentation as well as with the BIM model'; and 'Data coordination are conducted on BIM'.

Table 4.18: Current BIM practices in execution of projects

What are the current practices in the execution of your projects?	Mean Score	SD	RII	Rank	Remark
Traditional design methods	2.53	1.52	0.31	9	Medium
CAD files (2D and 3D) are primarily used	**3.69**	**1.44**	**0.50**	**1**	**High**
Construction site is provided with the traditional paper version of the documentation	3.33	1.52	0.46	2	Medium
Data coordination are conducted on BIM	2.82	1.55	0.35	4	Medium
CAE files BIM browsers are used, e.g. Autodesk *Navisworks*	2.71	1.33	0.33	6	Medium
Collision detection by any BIM software	2.27	1.50	0.27	14	Low
Projects having a central file on the company's server with local files on PC's	2.50	1.72	0.32	11	Medium
File synchronisation at specific intervals carried out on projects	2.38	1.50	0.30	12	Low
Construction sites are provided with the traditional paper version of all documentation as well as with the BIM model	2.82	1.67	0.35	3	Medium
Collisions effectively eliminated in the design phase and no clashes on the site	2.38	1.48	0.30	13	Low
During design, fewer redesigns, revisions and changes	2.81	1.53	0.38	5	Medium
Accurate ordering of materials and elements	2.70	1.62	0.35	7	Medium
Quantity of materials consistent throughout the project duration	2.67	1.54	0.33	8	Medium
No unnecessary or incompatible elements	2.53	1.52	0.31	10	Medium

The three least occurring practices which were only carried out to a 'Low' extent and were ranked 12th, 13th and 14th included 'File synchronisation at specific intervals carried out on projects'; Collisions effectively eliminated in the design phase and no clashes on the site'; and 'Collision detection by any BIM software'. This shows that project sites in Nigeria are yet to enjoy the full benefits of BIM which include clash detection and cost reduction (Eastman *et al.*, 2011).

4.3.6 Level of BIM adoption in project life cycle

The level of adoption of BIM for carrying out various tasks at different stages of the project lifecycle was assessed in this subsection and the results were presented in Table 4.19.

Table 4.19: BIM adoption in project life cycle

Rank your projects on BIM adoption on the following project life cycle performance.	Lifecycle	Mean Score	SD	Rank	Remark
Existing condition modelling	Planning	2.68	1.64	15	Medium
Cost estimating	Planning	2.83	1.70	7	Medium
Phase planning	Planning	2.76	1.67	11	Medium
Programming	Planning	2.66	1.74	17	Medium
Site analysis	Planning	2.85	1.79	6	Medium
Design reviews	Planning	3.13	1.75	2	Medium
Design reviews	Design	2.98	1.64	4	Medium
Design authoring	Design	3.14	1.65	1	Medium
Energy analysis	Design	2.54	1.63	19	Medium
Structural analysis	Design	3.02	1.71	3	Medium
Lighting analysis	Design	2.73	1.66	12	Medium
Mechanical analysis	Design	2.73	1.57	13	Medium
Other engineering analysis	Design	2.69	1.75	14	Medium
LEED evaluation	Design	2.37	1.73	24	Low
Code validation	Design	2.32	1.82	25	Low
3D coordination	Construction	2.78	1.49	10	Medium
Site utilisation planning	Construction	2.83	1.55	8	Medium
Construction system design	Construction	2.93	1.60	5	Medium
Digital fabrication	Construction	2.68	1.56	16	Medium
3D control and planning	Construction	2.79	1.63	9	Medium
Record model	Construction	2.63	1.64	18	Medium
Record model	Operate	2.38	1.71	23	Low
Maintenance schedule	Operate	2.29	1.71	26	Low
Building system analysis	Operate	2.53	1.78	20	Medium
Asset management	Operate	2.43	1.77	22	Low
Space management/tracking	Operate	2.44	1.80	21	Low
Disaster planning	Operate	2.26	1.82	27	Low

Only seven (7) tasks out of 27 utilised BIM to a 'Low' extent; the rest 20 tasks involved the use of BIM to a 'Medium' extent. The seven tasks associated with low utilisation of BIM were located within the 'design' and 'operate' phases of the lifecycle of projects. Examples of these tasks include LEED evaluation, Code validation and Maintenance schedule.

It was observed that almost all of the tasks that are needed for the delivery of construction projects by project managers utilised BIM to at least a 'Medium' extent. Low use of BIM was mostly associated with post-construction operation of projects. The professionals involved with this are mostly Estate Managers and Valuers as well as Facility Managers. This particular class of professionals were not included in the data collection survey; this might be responsible for the results that show a low use of BIM during the operation phase of project lifecycle.

4.3.7 Level of BIM adoption in project execution in the last ten years

This final subsection of the third part of Chapter Four dealt with the use of BIM in project execution over the past ten years. As has been discovered in previous sections of this chapter, professionals in the NCI have been more involved with the use of BIM Level 0 and BIM Level 1. It was therefore not a surprise that respondents agreed that these two BIM Levels (0 and 1) had been adopted in projects to a 'Medium' extent in the last 10 years (see Table 4.20). This meant that construction professionals still practice 'Hand drawing, 2D CAD drafting, and distribution of project design and/or production information via paper or electronic form e.g. PDF. This is usually for the purposes of tendering, contractor selection, contract valuation or final account settlement.

The more advanced BIM Level 2 has been adopted only to a 'Low' extent. However most of the benefits of BIM that have been identified in construction management literature have been associated with the use of higher BIM Levels, such as 2 or 3. From BIM Level 2, the process of project delivery begins to be seamlessly paperless and real-time. Kori and Kiviniemi (2015)have identified that countries like Finland, USA, UK, Australia, Netherlands, Singapore, Hong Kong Norway, and Denmark among others have adopted BIM technologies and are experiencing significant benefits in construction project delivery.

Table 4.20: BIM adoption in last ten years

What BIM level will you situate your project execution in the last ten years?	Mean Score	SD	Rank	Remark
Level 0: Hand drawing, 2D CAD drafting, distribution via paper or electronic form e.g. PDF	2.67	1.64	2	Medium
Level 1: A mixture of 3D CAD for concept work and 2D CAD for drafting of statutory approval, documentation and production information containing architecture design, construction design, installation design, landscape design, Bill of Quantities, Cost estimates and distribution via paper or electronic forms	3.12	1.63	1	Medium
Level 2: 3D models with a database containing all the above information in (2), parametric modelling, allowing quick implementation of changes in the 3D model, allowing for an extension of BIM 4D (time variable); BIM 5D (cost variable); BIM 6D (sustainability) and BIM 7D (facility management).	2.23	1.53	3	Low

4.4 Existence of government construction strategy for the adoption and implementation of BIM in the Nigerian construction industry

This fourth section of the chapter focuses on the analysis of data carried out towards meeting the third Objective of the study, which was 'To ascertain the existence of government construction strategy for the adoption and implementation of BIM in the Nigerian construction industry'. Mean score analysissupported by standard deviation was employed in ranking the various aspects of government construction strategy for the use of BIM in the NCI. The results were reported in tabular form.

4.4.1 Source of BIM knowledge in the Nigerian Construction Industry (NCI)

Most of the construction professionals who have some knowledge of BIM have acquired it by teaching themselves. This was revealed from the results presented in Table 4.21, which ranked 'self-taught' as the primary mode of BIM knowledge acquisition (Mean Score 2.79, ranked 1^{st}). Professional bodies in the construction industry also serve as an important source of BIM knowledge (Mean Score 2.65, ranked

2nd). BIM training centres and In-house training were ranked 3rd and 4th respectively. It was noteworthy that respondents claimed to patronise all of the sources of BIM knowledge only to a 'Medium' extent. More effort would thus be needed to aggressively make BIM knowledge available to construction practitioners, if the goal of increasing the use of BIM in the NCI is to be achieved in the near future. This is why (Ahmed and Houque, 2018) listed the barriers of BIM adoption to include the Training expenses and the learning curve that are too expensive.

Table 4.21: Source of BIM knowledge

In your opinion, Nigerian Construction practitioners' knowledge of BIM is gotten through the following?	Mean Score	SD	Rank	Remark
BIM training centres	2.57	1.66	3	Medium
Self-taught	2.79	1.62	1	Medium
In house training	2.56	1.44	4	Medium
Professional bodies	2.65	1.42	2	Medium
Others	2.21	1.57	5	Low

4.4.2 Investment in BIM by organizations in the Nigerian Construction Industry

Respondents were asked to volunteer an opinion on the extent to which their organisation invests in BIM. The results were ranked using Mean score analysis and are presented in Table 4.22. Irrespective of the type of employer, respondents were neutral as regards investment in BIM. Although no further questions were asked in this regard, the results of the analysis could be interpreted in two ways. Either the respondents did not have sufficient knowledge of investment in BIM by their organizations, or the investment was of such anegligible amount that they could neither agree nor disagree outright with the statement. Either way, it gives cause for concern and should encourage a move towards increased expenditure on BIM technologies for construction projects in the NCI.

Table 4.22: Investment in BIM

Does your organisation invest in BIM?	Mean Score	SD	RII	Rank	Remark
All respondents	3.02	1.27	0.47		Neutral
Consultant	3.06	1.03	0.48	1	Neutral
Contractor	2.94	1.39	0.46	2	Neutral
Government	2.80	1.79	0.47	3	Neutral

4.4.3 Major barriers to BIM adoption in respondents' field of practice

The extent to which four identified circumstances served as barriers to the adoption of BIM in the NCI was explored in this subsection, and presented in Table 4.23. It was discovered that the high cost of softwares was viewed by respondents as the most extensive barrier to BIM (Mean Score 3.63, ranked 1st). The 'resistance to change' of the stakeholders in the NCI was the second highest ranked barrier (Mean Score 3.27). The third and fourth ranked barriers were 'Lack of BIM training centres' and 'Lack of BIM specialists', which had Mean Scores of 2.91 and 2.67 respectively.

Table 4.23: Barriers to BIM adoption

What in your view are the major barriers to BIM adoption in your field of practice?	Mean Score	SD	RII	Rank	Remark
Resistance to change	3.27	1.42	0.46	2	Medium
Lack of BIM specialists	2.67	1.65	0.38	4	Medium
Expensive software	**3.63**	**1.57**	**0.50**	**1**	**High**
Lack of BIM training centres	2.91	1.56	0.43	3	Medium
Others	2.08	1.66	0.17	5	Low

This result highlights the importance of finance to the widespread adoption of BIM within the NCI. BIM software are expensive not only because of the amount of money that must be paid to buy them, but also in terms of the costs of maintaining and running the software. The need to have unfettered and unbroken access to electricity and internet connectivity is a major source of the expense involved in the use of BIM. This finding agrees with (Ahmed and Houque, 2018) that the barriers of BIM adoption include the Social and habitual resistance to change, High cost of software purchasing, Traditional methods of contracting, Training expenses and the learning curve are too expensive.

4.4.4 Roles currently being played by government in BIM adoption and implementation in Nigeria

This subsection examined six (6) roles that government could play in encouraging the adoption of BIM within the NCI. The roles were ranked based on the strength of the semantic scores awarded by the respondents. 'Government pioneering and moving to adopt BIM in all of its projects' was ranked 1st, while 'A government construction strategy on the adoption and implementation of BIM in public funded projects' was ranked 6th. However, it was observed that the Mean Score values of all of the six roles fell within the range 0.50 – 1.49, which corresponded to 'Very Low' on the semantic scale employed in the research questionnaire.

Table 4.24: Roles of government in BIM adoption and implementation

Is the government playing any of the following roles currently in BIM adoption and implementation in Nigeria?	Mean Score	SD	RII	Rank	Remark
A government construction strategy on the adoption and implementation of BIM in public funded projects	1.22	1.46	0.19	6	Very Low
Any government recommendations to encourage, specify or mandate the use of BIM for publicly funded projects	1.38	1.48	0.21	2	Very Low
Government pioneering and moving to adopt BIM in all of its projects	1.43	1.53	0.21	1	Very Low
Government planning a BIM implementation strategy for the construction industry in Nigeria	1.26	1.45	0.19	5	Very Low
Government providing incentives and support for the implementation of BIM technology in Nigeria	1.33	1.52	0.19	3	Very Low
Government investing in research and development in BIM technology in Nigeria	1.33	1.43	0.19	4	Very Low

The implications of these results are wide and far-reaching. Globally, governments serve as facilitators for the adoption of new or innovative technologies. To perform this role successfully, governments must have a clear vision and have developed clear-cut policies on how to realise such vision. More importantly, governments must be perceived to be actively working towards the adoption of the innovative technology in question, in this case, BIM. This does not appear to be the case in Nigeria; respondents in this study, who are all construction professionals, do not believe that government is actively working for the adoption of BIM in the NCI. This is unlike the case in the United Kingdom, where the BIM mandate was implemented in April 2016 (NBR, 2017).

4.5 Improving the BIM Level in Operation in the Nigerian Construction Industry

This fifth section of the chapter focuses on the analysis of data carried out towards meeting the fourth Objective of the study, which was 'To provide recommendations on how to improve the BIM level in operation in the Nigerian Construction Industry'. Mean score analysisand standard deviation were used to rank the various actions that could be encouraged to improve the use of BIM in the NCI. The results were reported in tabular form.

4.5.1 Activities required from the government

This subsection collated the views of construction professionals on government efforts to promote BIM, from the perspective of Consultants and Contractors. From the results presented in Table 4.25, professionals employed by consultants considered that government has been least influential promoting BIM in the following areas: (i) providing a strategy on the adoption and implementation of BIM in public funded projects; (ii) planning a BIM implementation strategy for the Nigeria construction industry; and (iii) providing incentives and support for the implementation of BIM technology.

On the other hand, professionals employed by contractors considered that government has been least influential promoting BIM in the following areas: (i)investing in research and development in BIM technology; (ii) providing incentives and support for the implementation of BIM technology; and (iii) mandating the use of BIM for publicly funded projects. These six statements have been fused into four Action Areas for Government as presented in Fig. 4.5.

Table 4.25: Activities required from government for BIM adoption and implementation

Is the government playing any of the following roles currently in BIM adoption and implementation in Nigeria?	Consultant			Contractor		
	Mean Score	SD	Rank	Mean Score	SD	Rank
A government construction strategy on the adoption and implementation of BIM in public funded projects	1.11	1.18	6	1.67	1.91	1
Any government recommendations to encourage, specify or mandate the use of BIM for publicly funded projects	1.44	1.38	2	1.31	1.55	4
Government pioneering and moving to adopt BIM in all of its projects	1.56	1.38	1	1.62	1.89	2
Government planning a BIM implementation strategy for the construction industry in Nigeria	1.33	1.50	5	1.38	1.56	3
Government providing incentives and support for the implementation of BIM technology in Nigeria	1.38	1.50	4	1.23	1.48	5
Government investing in research and development in BIM technology in Nigeria	1.44	1.29	3	1.17	1.64	6

The recommendations that emanate from the survey of construction professionals reveal that it is necessary for government to have an Implementation Strategy Plan for BIM first of all. Embedded in this Plan will be legislation that will make the use of BIM mandatory for all projects.This is nothing new; in the United Kingdom, the BIM mandate was implemented in April 2016 (NBR, 2017). It is the first step to a universal adoption of BIM within a nation's construction industry. Other aspects of the Plan are incentives that will support the use of BIM and funding for BIM research and development (R&D).

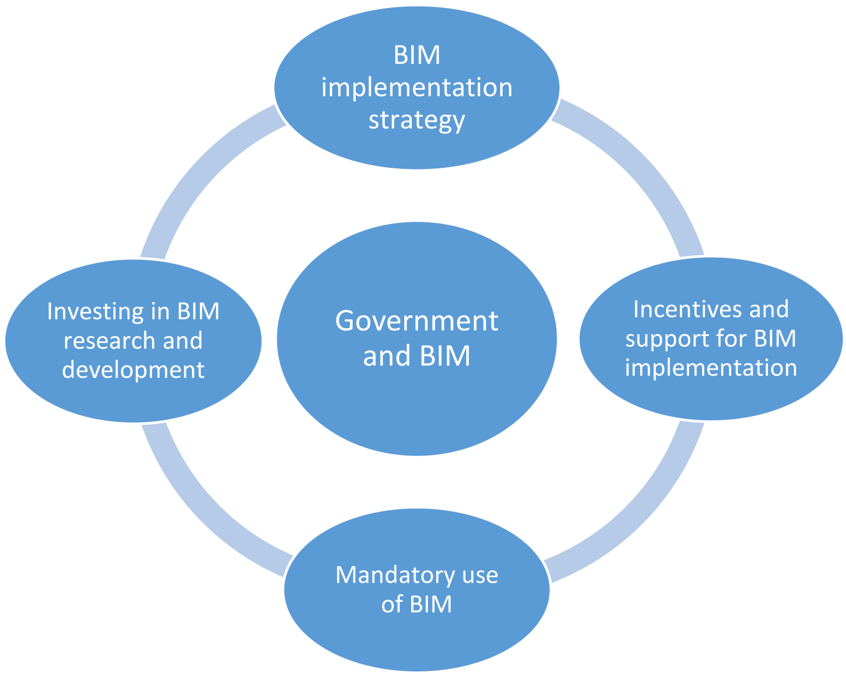

Figure. 4.5: BIM Action Areas for Government

Figure 4.5 presents BIM action areas for government participation in the implementation of BIM strategy (NBR, 2017).

4.5.2 Problems affecting construction firms

The second major group of stakeholders in the NCI which was surveyed in this study is composed of contractors who operate the firms that undertake the actual construction works on site. This group of stakeholders are crucially important, because they will be responsible for actually using BIM technologies to construct buildings and other projects. it is necessary to identify and understand the problems faced by contractors in the NCI, as a way of improving the adoption of BIM in the industry. Table 4.26 and 4.27 presented information on different aspects of the problems that contractors face.

The respondents in this study who worked for contractors opined that ‘expensive software’s and ‘resistance to change’ are the two key problems that contractors have to resolve in order to improve the use of BIM in the NCI. The results revealed that these two problems, along with a ‘lack of BIM training centres’, had a ‘medium’ level of influence, as barriers to BIM adoption, on the NCI.

Table 4.26: Problems affecting construction firms’ BIM adoption efforts

What in your view are the major barriers to BIM adoption in your field of practice?	Contractors		
	Mean Score	SD	Rank
Resistance to change	3.00	1.62	1
Lack of BIM specialists	2.43	1.50	4
Expensive software	3.00	1.81	1
Lack of BIM training centres	2.60	1.50	3
Others	1.50	1.64	5

Identifying solutions to these problems require examining the components of the costs involved in use of BIM. Likely costs include (i) capital (purchase) cost; (ii) electricity costs; (iii) Internet connectivity costs, and (iv) Wages for skilled operators. It might be necessary for the government to offer some form of assistance to contractors towards meeting these costs as incentives to adopt BIM. There is compelling evidence (Ibrahim *et al*., 2014) that on their own, firms are unable to overcome the debilitating effects of barriers such as High cost of training, Lack of trained professionals to handle the tools, High Cost of integrated software/models for all professionals, Poor internet connectivity, and frequent power failure.

4.5.3 Problems affecting construction professionals

Obtaining requisite knowledge of how to use BIM is a challenge for construction professionals in Nigeria. Respondents who worked for consultants obtained most of their knowledge of BIM through the efforts of the professional bodies in the construction industry. Those professionals employed by contractors had learnt about

BIM through self-learning efforts. Professionals in government service acquire BIM knowledge through both self-learning and in-house training.

It was noted from the result of analysis as presented in Table 4.27 that none of the different avenues through which professionals acquire BIM knowledge was of higher than 'medium' impact (where Mean Scores fall between 2.50 and 3.49). This is one area in which government can have a positive impact by investing in easy and effective dissemination of BIM knowledge. This will help to bring down the astronomical costs of training and certification, which according to (Ibrahim *et al*.,2014) are some of the barriers to adoption of BIM in the construction industry in Nigeria.

Table 4.27: Avenues for BIM training

In your opinion, practitioners' knowledge of BIM is gotten through?	Consultant				Contractor			Government		
	Mean Score	SD	Rank	Extent	Mean Score	SD	Rank	Mean Score	SD	Rank
BIM training centres	2.67	1.64	2	Medium	2.21	1.37	4	2.33	1.83	3
Self-taught	2.28	1.27	4	Low	3.00	1.60	1	3.00	1.91	1
In house training	2.41	1.37	3	Low	2.31	1.25	3	3.00	2.16	1
Professional bodies	2.83	1.34	1	Medium	2.60	1.18	2	2.00	2.06	4
Others	2.20	1.75	5	Low	1.86	1.35	5	2.00	1.71	4

4.6 Summary of Findings

i. Within the NCI, BIM awareness and acceptance are at medium levels, with only 'AutoCAD' BIM software enjoying a 'High' frequency of use. There exists a 'Medium' level of knowledge about BIM levels 0 and 1, and BIM is generally practiced to a 'Medium' extent through use of selected teams. The most common BIM practices include distribution of contract or production information 'via paper or electronic form e.g. PDF'; use of '2D CAD for drafting of statutory approvals, documentation and production information', and the mixing of '3D CAD for concept work'. About two-thirds of all projects carried out by surveyed professionals utilised BIM, which was mostly applied in the ‘Design’, ‘Detailing’ and ‘Budget and estimates’ stages of construction projects.

ii. BIM adoption had a noticeable impact in four reviewed aspects of project performance; ‘Greater control’, ‘Improved collaboration’, ‘Conflict resolution’, and ‘Reduction in labour’; however, the design performance of projects improved in only 1 out of 8 aspects(‘Improved conflict resolution’). BIM adoption has had ‘Medium’ impact on all eight building elements that were reviewed. BIM was used to a ‘High’ level in the case of four tasks; Elevation views, Drawings in 2D/3D, Sections and cross sections, and CAD software for design and documentation. Most of the tasks that are needed for the delivery of construction projects (20 tasks were identified) utilised BIM (at Levels 0 and 1) to a ‘Medium’ extent within the last 10 years.

iii. Most construction professionals acquired knowledge of BIM by teaching themselves; in fact, all four sources of BIM knowledge tested in this study were used only to a ‘Medium’ extent. There is little or no information about investment in BIM, and high cost of software was viewed as the most extensive barrier to BIM. Performance of six identified roles by government was adjudged ‘Very Low’.

iv. To improve BIM adoption and use in the NCI, government must have an Implementation Strategy Plan for BIM along with legislation making BIM mandatory, incentives supporting the use of BIM and funding for BIM research and development (R&D). Three BIM barriers (‘Expensive software’, ‘resistance to change’ and ‘lack of BIM training centres’) had a ‘Medium’ level of influence.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study aimed to assess the adoption of Building Information Modelling (BIM) in the Nigerian Construction Industry (NCI), in order to reveal the effect of BIM adoption on projects carried out by construction firms. Four objectives were formulated towards achieving this aim: ascertaining the level of BIM in operation, determining the impact of BIM in the project life cycle, ascertaining the existence of government construction strategy for BIM, and recommending how to improve the level of BIM in the NCI. Following the analysis of data collected through a survey of construction professionals, the following conclusions have been reached.

The NCI is both aware of, and has accepted BIM to what can be described as a ‘medium level’ of knowledge about BIM level 0 and BIM level 1. BIM software use is dominated by ‘AutoCAD’ package, and is generally practiced through use of selected teams. The most common BIM practices include distribution of contract or production information ‘via paper or electronic form e.g. PDF’ and use of ‘2D CAD for drafting of statutory approvals, documentation and production information’, which are indicative of BIM Level 1. Although two-thirds of projects carried out by surveyed professionals utilised BIM, this was mostly in the ‘Design’, ‘Detailing’ and ‘Budget and estimates’ stages of construction projects. Based on the foregoing findings, it was concluded that BIM use in the NCI is still at a rudimentary level, but that great potential for improvement exists, if the right environment (political, legislative, contractual, technical) is provided.

With respect to the impact of BIM in the NCI, the study found that BIM adoption had a noticeable impact in four project performance aspects; use of BIM resulted in ‘Greater control', 'Improved collaboration', 'Conflict resolution', and 'Reduction in labour'. Although BIM was used to a 'High' level in some project tasks such as Elevation views, Drawings in 2D/3D, Sections and cross sections, and CAD software for design and documentation; projects design improved only as regards 'conflict resolution'. The adoption of BIM has had a 'Medium' impact on no less than eight building elements, and most of the tasks necessary for the delivery of construction projects (20 tasks were identified) utilised BIM (at Levels 0 and 1) to a 'Medium' extent within the last 10 years. These findings strongly suggest that BIM is available in the NCI, has had noticeable impact, and that the industry is yet to enjoy the full benefits of BIM use.

This study has also concluded that very little evidence exists of the existence of any government strategy for BIM in the NCI. In fact, the performance by government of the six roles identified with it was adjudged 'Very low'. Construction professionals mostly acquire knowledge of BIM by teaching themselves; there is little or no information about investment in BIM, and high cost of software was viewed as the most extensive barrier to BIM. Four key strategies have been identified as crucial to improve BIM adoption and use in the NCI, in response to the three main BIM barriers ('Expensive software', 'resistance to change' and 'lack of BIM training centres') revealed by the study.

5.2 Recommendations

The following recommendations have emanated from the survey of construction professionals as carried out in this study.

i. It is imperative that the Federal and State governments design and promulgate an Implementation Strategy Plan for BIM after due consultation with all relevant stakeholders in the NCI. The key provisions of such Plan will be (i) legislation that will make the use of BIM mandatory for all projects, (ii) incentives that will support the use of BIM and (iii) funding for BIM research and development (R&D).

ii. It was also recommended that in order to increase BIM penetration among firms in the NCI, government must offer some form of assistance to contractors towards meeting BIM costs. The costs involved in use of BIM include (i) capital (purchase) cost; (ii) electricity costs; (iii) Internet connectivity costs, and (iv) Wages for skilled operators. Subsidies for these costs tied to use of BIM at specified levels (such as BIM Level 1 or Level 2) could be included as items in the Preliminaries of construction contracts.

iii. Government can impact positively on BIM in the NCI by investing in easy and effective dissemination of BIM knowledge. The aim will be to bring down the astronomical costs of training and certification, which are some of the barriers to adoption of BIM in the construction industry in Nigeria. This can be done through existing government knowledge agencies such as the Administrative Staff College of Nigeria (ASCON) in partnership with professional associations within the NCI.

iv. Professional bodies of the various professionals in the construction industry must as a matter of urgency prioritize workshops and seminars on the BIM training

5.3 Contribution to Knowledge

From the onset, this study aimed to assess the adoption of Building Information Modelling (BIM) in the Nigerian Construction Industry (NCI). It has been able to generate knowledge that BIM use in the NCI is still at a rudimentary level. This is based on the finding that BIM is available in the NCI, has had noticeable impact, and that the industry is yet to enjoy the full benefits of BIM use. Another contribution to knowledge is the discovery that very little evidence exists of the existence of any government strategy for BIM in the NCI; that, in fact, government performance of the six roles identified with it has been ‘Very low’. The study has also contributed to knowledge by identifying ‘Expensive software’, ‘resistance to change’ and ‘lack of BIM training centres’ as the three main BIM barriers in the NCI.

5.4 Areas for Further Study

The following areas have been under-explored in this study; it is thus suggested that future studies should focus on them.

i. The effect of type and size of projects on the adoption of Building Information Modelling (BIM) within the Nigeria Construction Industry.
ii. The influence of level of formal education and professional training on the willingness of construction professionals to adopt BIM techniques.

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LIST OF APPENDICES

APPENDIX 1 - ANALYSIS OF DEMOGRAPHICS

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Kurtosis		-1.205
Std. Error of Kurtosis		.674
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Valid	Architecture	10	10.3	20.8	20.8
	Building	4	4.1	8.3	29.2
	Engineering	3	3.1	6.3	35.4
	Project Management	2	2.1	4.2	39.6
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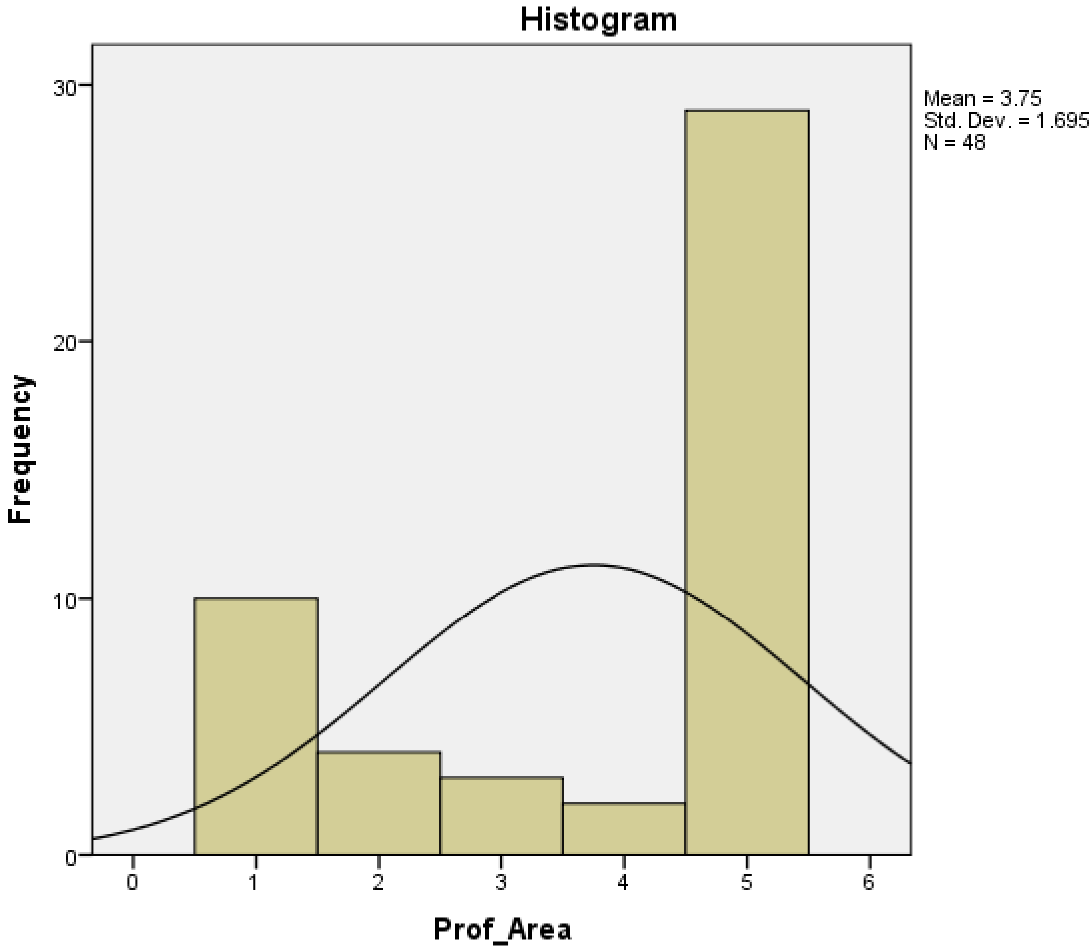


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Valid	Consultant	18	18.6	34.6	34.6
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	Public Sector	5	5.2	9.6	76.9
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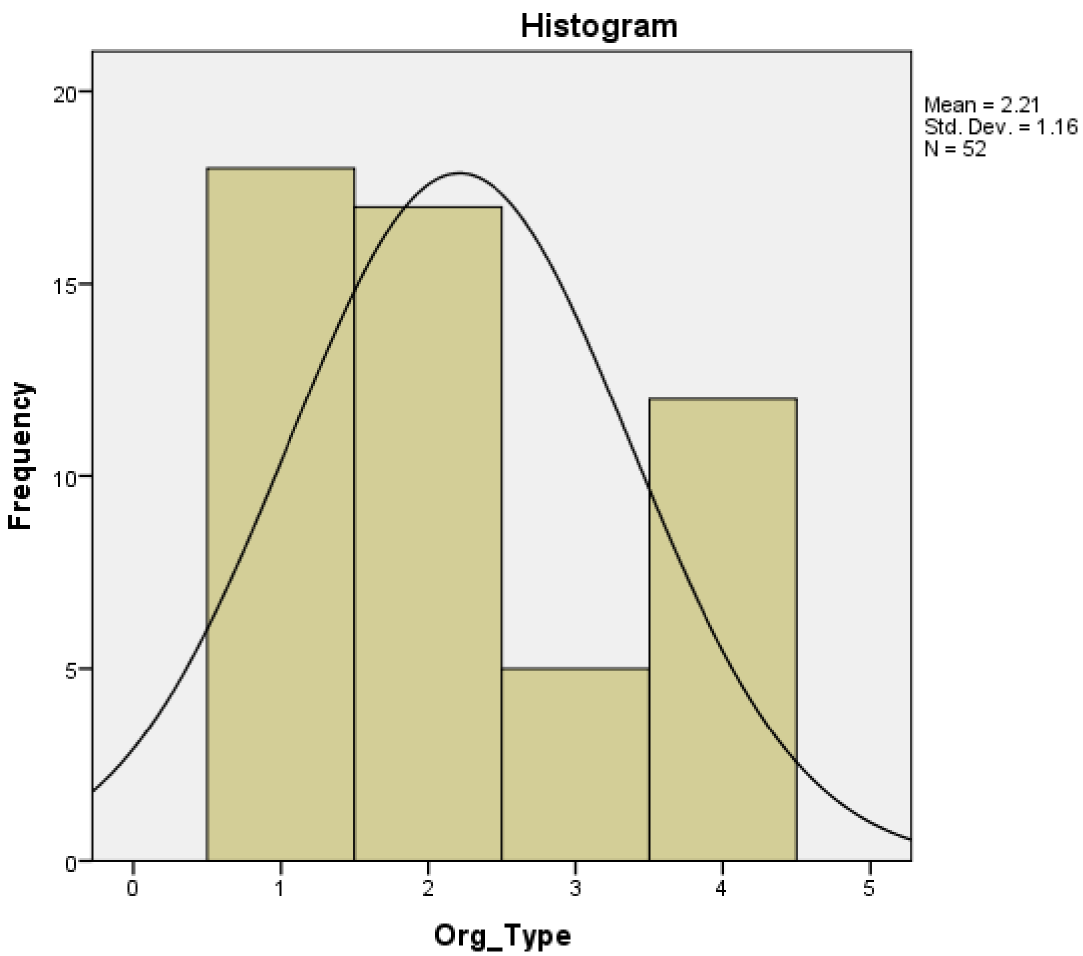


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Org_Scale

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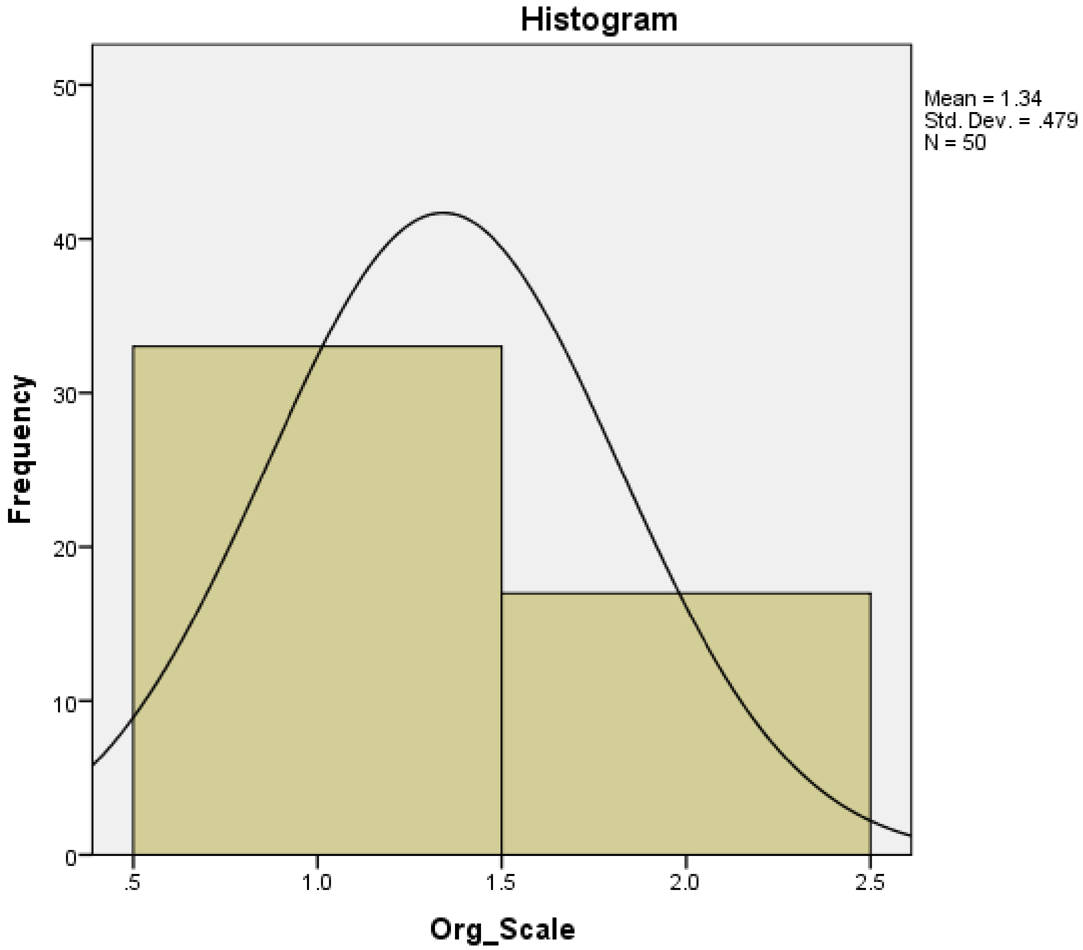

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Exp_Yrs

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	10 - 15 years	11	11.3	21.6	92.2
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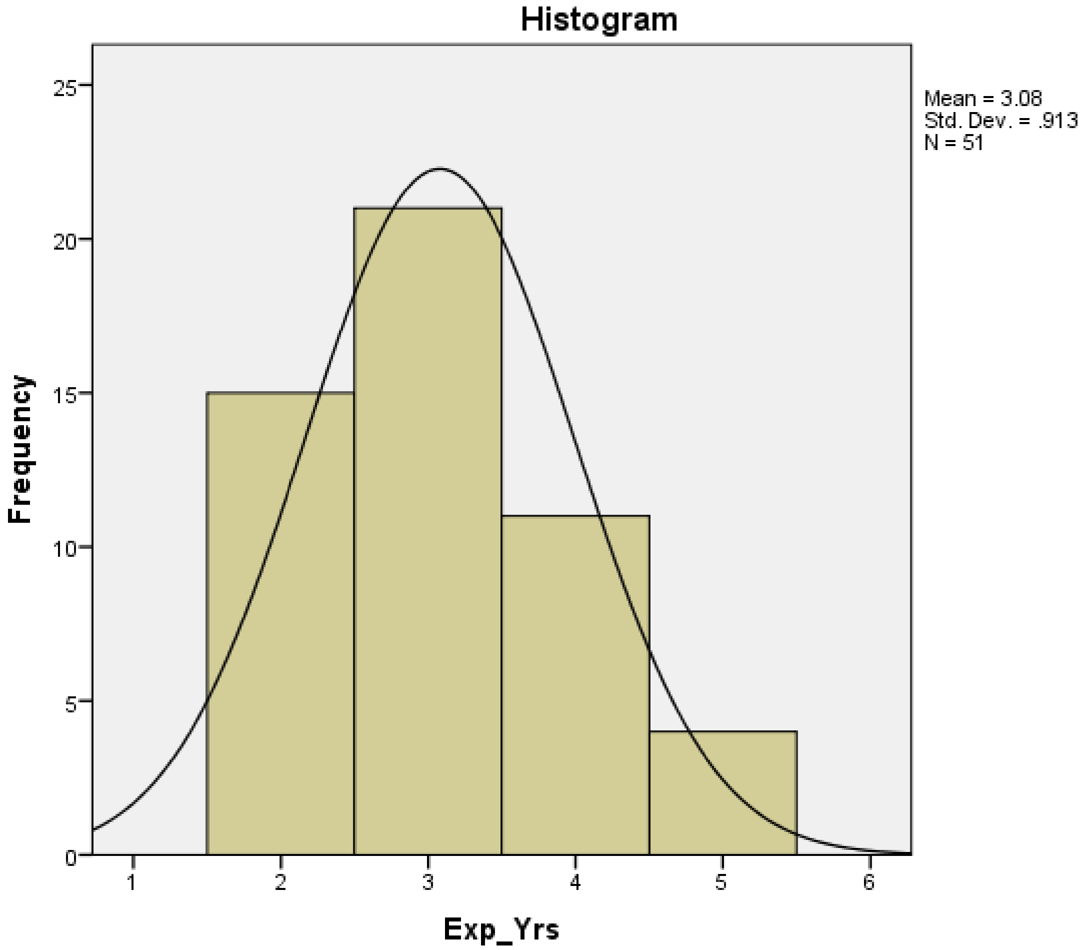
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