AN APPRAISAL OF BUILDING INFORMATION MODELLING TECHNOLOGY IN BUILDING CONSTRUCTION AND MAINTENANCE IN AFRICA: A CASE OF NIGERIA AND SOUTH AFRICA

BY

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ABSTRACT

Building Information Modelling technology (BIM-T) continues to gain attention. Its adoption creates a platform that allows the built environment professionals to share project information through a common database. At the same time, there is an increased perception that implementing BIM on construction projects will positively influence building production throughout its lifecycle. Recent studies have revealed a low level of BIM implementation in the African construction industry. Currently, the utilisation of BIM for building production has received a significant acceptance rate in developed regions, while in African countries, it is still at an infant stage. Moreover, previous studies have established that BIM application comes with various barriers. These barriers contribute to its low adoption, application and implementation. Nevertheless, there are still some notable benefits and impacts on building production, which have been the main drivers for its continual adoption. Therefore, this study aimed to research BIM-T applications in African countries, focusing on the Nigerian and South African construction industries. The goals are to assess its level of awareness, usage, barriers hindering its application/implementation and benefits accruable with its adoption. BIM impacts the building production lifecycle and determines the strategies to promote its application among construction professionals for sustainable construction in developing countries.

To achieve the objective of this research, an extensive review of the literature was conducted on usage, barriers to BIM adoption, application/implementation, benefits of adopting BIM, its impacts on building production, and strategies to promote its application/implementation. A structured questionnaire elicited constructive data from the Nigerian built environment professionals (NIA, NIOB, NIQS, and NSE) and the South African construction-related professionals (SACPCMP). The web-based (Google form) questionnaire was distributed online. According to the distribution among the professionals, 276 and 105 respondents indicated their willingness and availability to participate in the research from Nigeria and South Africa, respectively. The generated data was analysed using the following descriptive measures: mean item score (M.I.S), relative important index (RII), ranking and frequency and quantitative inferential analysis (factor analysis, pairwise comparison, one-way ANOVA and Kruskal-Wallis).

It was found that there is a significant increase in the level of BIM awareness among Nigerian and South African construction professionals compared to previous findings. 98.55% and 96.19% of respondents, respectively affirmed that they are aware of BIM. Nevertheless, these findings established that there are still BIM-related barriers peculiar to both countries; the top common three barriers are low computer skills among some of the professionals, habitual resistance to change from the traditional style of design and build, and government's unwillingness to support BIM use. These barriers could be responsible for the professional's low level of BIM tool usage. The study also revealed that all 13 identified BIM benefits are significantly important in both countries. From this, it could be concluded that BIM application has significantly improved the production of buildings through its contribution to performing tasks from building design to post-construction stages. Finally, the respondents identified the need for foundational knowledge in an educational institution on BIM tool use and its applications as a critical area of focus that could assist the promotion of BIM.

This study has extensively documented the various research contributions carried out in this study's area of focus. The preliminary survey result concludes that the findings will assist the professional body in making intelligent decisions and adequate measures to advance the adoption, application/implementation of BIM among their members. It will also inform the institutions about what is required from their construction graduates to improve their employability in the industry.

Keywords: BIM, construction management, innovative technology, building lifecycle, sustainable construction.

DECLARATION

I, JAMES OLAONIPEKUN TOYIN, declare that all the information in this dissertation has been collected and presented following the Durban University of Technology's ethical rules and academic conduct. I also declare that this dissertation represents my work, both in conception and execution. This work has not been submitted in any form for another degree at any university or institution of higher learning. All information cited from published or unpublished works has been acknowledged.

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DEDICATION

This work is dedicated to the Almighty God, My Mother: Prophetess Adebola Abigail Toyin, and Late Primate Toyin E. Ige.

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LIST OF PUBLICATIONS

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Journal Article

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Book Chapter

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Conference paper

1. Toyin, J. O. & Mewomo, M. C. Barriers to Successful BIM Applications: A Literature Review. In: OKORO, C. T. & ONOSOSEN, A., eds. Proceedings of the DII-2021 International Conference, 2021 Virtual Via Livingstone, 2021 Zambia. The Development and Investment in Infrastructure (DII) Conference Series, 413-432.
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2. Oyewole, M. D., Mewomo, M.C., Toyin, J.O. Synthesis of corn cob ash as partial replacement of cement in concrete: a review.

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LIST OF ABBREVIATIONS

AEC- Architecture, Engineering, and Construction

BAN- BIM Awareness Nigeria

BASA- BIM Awareness South Africa

BB- BIM Benefit

BCN- Barrier Code Nigeria

BCSA- Barrier Code South Africa

BI- BIM Impact

BIM- Building Information Modelling

BIM-T: Building Information Modelling Technology

BUN- BIM Use Nigeria

BUSA- BIM Use South Africa

MIS- Mean Item Score

NIA- Nigerian Institute of Architects

NIOB- Nigerian Institute of Builders

NIQS- Nigerian Institute of Quantity Surveyor

NSE- Nigerian Society of Engineers

O&M- Operation and Maintenance

PCA- Principal Component Analysis

RII- Relative Important Index

SACPCMP- South African Council for the Project and Construction Management Professions

LIST OF APPENDIXES

CHAPTER ONE: INTRODUCTION

1.1 INTRODUCTION

This introductory chapter provides background information on the research area. The study sought to discover how widely BIM technology is utilised in the building construction industry. This research examined the levels of awareness, barriers, impacts, benefits, and ways to promote BIM application in African countries. In addition, this chapter outlines the research's aim and objective.

1.2 BACKGROUND

Construction projects worldwide are usually complex, characterised by heavy bureaucratic processes, high technicality, time commitment and substantial cost implications (Arayici, 2015). These challenges are unavoidable red flags for all stakeholders in the construction industry. These challenges are caused by the huge fragmentation, lack of control and coordination of construction processes that result from inadequate communication among the various phases of the building lifecycle (Onungwa and Uduma-Olugu, 2017). In this decade, the construction community is gradually moving from the concept of 2D (two-dimensional) and 3D (three-dimensional) design and construction processes to improved design and construction processes, which takes us to the era of 4D (four-dimensional), 5D (five-dimensional), and 6D (six-dimensional) to overcome those challenges. However, the most current technique is the 7D (seven-dimensional) conceptualisation of the construction process through the advent of Building Information Modelling (BIM). 7D BIM is all about operations and facility management. The dimension is used to track essential asset data such as its status, maintenance and operation manuals, warranty information, technical specifications and so on for future use (BIM, 2022).

The importance of BIM technology since its inception cannot be over-emphasised. Deng *et al*. (2020) and Toyin and Mewomo (2022a) noted that Professor Chuck Eastman originally proposed the BIM prototype in 1975. He offered to "build a computer-based description of a building", which transformed into the BIM technology that the construction professionals are enjoying to date for its simplicity. Moreover, recent finds justify the claims that BIM represents a fundamental change to the traditional ways in which construction professionals function and communicate (Toyin and Mewomo, 2023). It allows for collaboration and ease of data sharing among construction professionals (Eastman *et al*., 2011). BIM was created to resolve inadequacies of the earlier Computer Aided Drawing (CAD). This modelling tool provides a working digital platform that incorporates all information about a building in an electronic file for various project stakeholders' use, especially the construction manager (Toyin and Mewomo, 2022b). According to Hamma-adama and Kouider (2019), for BIM technology to work accurately, there is a need for specific tools to manage the construction processes and deliver projects based on specifications. However, to do so, these various processes must be efficiently coordinated; therefore, a construction management (CM) technological model such as BIM is required. Topliss Hurst and Skarratt (2007) and Karakurt (2019) defined CM as a professional service that delivers effective management of a project's time, cost, quality, safety, scope, and function to the project's owner(s). CM is a stage in construction where the conceptual designs are processed through careful coordination to full realisation. According to Oral (2010), CM means completing construction-related projects by eradicating design difficulties and keeping costs under control within the minimum time. Based on this fact, managing and controlling project activities is imperative to achieving scope, cost, and time objectives (Hanna and Skiffington, 2010). Therefore, the adoption of BIM into CM practice has redefined the roles of the construction manager as the overall coordinator of the different fragmented phases (planning, design, construction, and post-construction phases). With the evolution of BIM, all professionals, especially the construction manager, must embrace this technology with the urgency it deserves (Toyin and Mewomo, 2022b). The construction manager needs to be conversant with most aspects, such as the uses, benefits, barriers and tools of this iconic technology to credibly perform the daunting and evolving tasks of delivering the building project to the client's satisfaction in terms of cost proportionality, quality, and durability. Despite findings by various scholars on advancement in the adoption rate of BIM for construction and maintenance, there is little or no evidence of investigation that explores the coverage to which BIM technology is used in building construction and maintenance management in developing regions (Meng *et al*., 2020; Mahamadu *et al*., 2019; Matějka and Tomek, 2017). Therefore, this study investigates the extent to which BIM technology is used for building construction and maintenance management in developing regions with a focus on South Africa and Nigeria.

1.3 PROBLEM STATEMENT

According to Cao *et al*. (2017) and Azhar *et al*. (2012), the construction industry, including those in developing countries, has long attempted to implement innovative technology that would lower project costs, boost productivity and quality work, shorten project delivery time, enhance project sustainability and minimise waste. The unavailability of such innovative technology has caused delays, time overruns, material wastage, low productivity, and lower value for money. This problem persists in countries that have yet to adopt innovative technology for managing construction activities. This does not exclude countries like South Africa and Nigeria (Cao *et al*., 2017; Toyin and Mewomo, 2022b). The findings of Moreno *et al*. (2019), Olapade and Ekemode (2018), Newton and Chileshe (2012) and Azhar *et al*. (2012) stated that BIM has recently achieved widespread attention and usage in the construction industry. Previously BIM attention and usage were not as widespread among the construction professionals in South Africa and Nigeria as expected. Hamma-adama and Kouider (2019) corroborated it in their study, stating that there was an increase from 28% in 2017 to 54% in 2018 among those professionals who are aware of and use BIM technology. This study, however, was designed for registered construction managers who supervise and manage the building process. To corroborate this further, Kassem *et al*. (2013) and Saka and Chan (2020) stated that previous research concentrated on assessing BIM roles and benefits in general and the adoption rate by small and large construction firms.

Similarly, Hamma-adama *et al*. (2018) conducted a study on the state of BIM adoption in Nigeria, investigating its awareness and adoption level and discussing its problems pertaining to the client, consultant and contractor. This study acknowledges that there are no notable BIM publications in building construction and maintenance management accessible in South Africa and Nigeria focusing on registered built environment professionals. This discovery led to a decrease in productivity and an increase in construction rework and wastage. Poirier *et al*. (2015) further explained the construction industry's productivity through the decades and indicated its remarkably steady and alarming decrease. He consequently stated that the traditional project delivery processes are becoming obsolete as the world evolves. Love and Edwards (2004) defined construction rework as “the unnecessary effort of redoing a function or activity done incorrectly for the first time in the construction process.” These reworks are usually a factor of managerial incompetence, that leads to errors, omissions, and changes, which often cause much cost overrun, stress, and discouragement. It is therefore, necessary for construction managers to integrate the usage of BIM to avert unpleasant occurrences.

Architectural design, structural analysis, and construction management have traditionally been the three different processes with distinct aims in building engineering operations. But then there is a fourth vital step, post-construction and/or maintenance, which is prone to human error at each phase. For instance, the quantity surveyor analyses, interprets and produces project estimates using a manually drawn plan. The construction manager subsequently uses this estimate to evaluate the project's cost. In the case of a big project with more complexity, there could be a snowball effect of errors, and no client would want to pay for an inaccurately managed project (Toyin *et al*., 2022). With the predominance of information technologies in the construction sector, combining design, construction, and post-construction operations is possible by integrating BIM and 4D technology (Hu *et al*., 2008; Liu and Issa, 2013; Vimonsatit and Foo, 2015; Ahankoob *et al*., 2018; Toyin and Mewomo, 2021; Toyin and Mewomo, 2023).

As a result, considerable adjustments must be made to a project's typical plan-build-operate building life cycle to utilise BIM properly. Eastman *et al*. (2011) claimed that BIM raises a firm's cost, which may restrict its use and needs a steep learning curve for professionals, particularly a construction manager. The report by Young *et al*. (2009) stated that about 50% of the construction sector is utilising BIM, with 87% of experienced users seeing a favourable return on investment with BIM and 93% believing that returns gained can increase the potential worth of BIM. Therefore, construction managers need to facilitate the urgent but gradual usage of BIM technology with the responsibility of ensuring quality and timely delivery of projects at a commensurate cost. This thesis will aim to mitigate these underlying gaps/problems in construction and maintenance management in South Africa and Nigeria through ensuring a better understanding of the benefits, impacts, and barriers of BIM technology. Appraising its use level, proffer solutions to ensure its rapid integration among construction managers.

1.4 AIM OF THE STUDY

This research's main aim is to investigate the extent to which BIM technology is used in building construction and building maintenance management among built environment professionals in South Africa and Nigeria. Also, suggest ways to continue or encourage its application through means of eradicating barriers and challenges facing it wider spread.

1.5 RESEARCH QUESTIONS

This study's proposed to find answers to the following research questions:

1. What is the awareness level and usage level of BIM-T among construction/maintenance managers in South Africa and Nigeria?

2. What are the barriers hindering the adoption/application of BIM-T in South Africa and Nigeria's built environment?

3. What are the benefits of using BIM-T in the construction and maintenance of building facilities in South Africa and Nigeria?

4. What are the impact of BIM-T applications on construction and maintenance projects?

5. What are the strategies required to promote BIM-T application among construction professionals for sustainable construction in developing countries?

1.6 OBJECTIVES OF THE STUDY

This study's objectives are to:

1. Assess the level of awareness and usage of BIM-T among construction/maintenance managers in South Africa and Nigeria.

2. Investigate barriers to the successful adoption/application of BIM-T in South Africa and Nigeria's built environment.

3. Assess the benefits of using BIM in the construction and maintenance of building facilities in South Africa and Nigeria.

4. Investigate successful BIM technology applications' possible impact on construction and maintenance projects.

5. Determine strategies to promote BIM-T application among construction professionals for sustainable construction in developing countries.

1.7 SCOPE

This research investigates the level of BIM Technology usage in construction and maintenance management. It involved only registered construction professionals practising in South Africa SACPCMP (South African Council for the Project and Construction Management Professions) and Nigeria NIA (Nigerian Institute of Architects), NIOB (Nigerian Institute of Building, NIQS (Nigerian Institute of Quantity Surveyor, and NSE (Nigerian Society of Engineer) (Lagos)]. The means of eliciting information from them is limited to an online web-based questionnaire. The analysis employed a quantitative close-ended and open-ended questionnaire method of eliciting information from the respondents.

1.8 SIGNIFICANCE OF THE STUDY

Before the advent of BIM, the construction industry operated in isolation. Each project team member was exclusively concerned with his/her interests, and the project suffered as a result because information required at different times for different disciplines during various project phases was not comprehensively complied with. Thus, the complete information needed for any construction project was not fully understood. In large industrial projects, for example, more than half of field challenges were linked to a lack of proper communication and design and more than half of contract changes were attributed to design discrepancies. Arayici (2015) opined that all stakeholders should obtain the entire design and proper document at an early stage of a project to to tackle difficulties. Tardif, Murray & Associates Construction Company from Canada, for example, demonstrated in one of their projects that they required 420 participant companies (including all suppliers and subcontractors), 850 participant individuals and 50 different types of documents totalling approximately 56 000 pages. The construction manager is at the centre of all stages of the development. They find it extremely difficult to handle a project of such magnitude. In South Africa and Nigeria, this crude method has been employed over the years and has been a leading facilitator of many errors and high construction costs. Combining all these processes is necessary to achieve the project's specifications effectively.

Project coordination is a technological and administrative discipline used to achieve one of the most significant parts of project construction and construction/maintenance management. Several studies on BIM adoption have recently been published in academic journals, focusing on preparation, awareness, degree of adoption, capacities (stages), barriers, and drives toward adopting and implementing BIM. But according to Ademci (2018), extremely few have conducted such research in construction/maintenance management in South Africa and Nigeria. Abubakar *et al*. (2014) opined that despite many years of discussions and research on the BIM idea and its adoption, construction industries in Africa had not received attention till 2010, when BIM was adopted in some aspects of the construction and renovations of stadia across South Africa in preparation for the 2010 FIFA World Cup that was held in the country. It was the first attempt to adopt BIM in South Africa and was limited to the design stages of construction. BIM was rarely used by construction and maintenance managers in the construction and post-construction (maintenance) phases. While in Nigeria, there have been reports of its adoption by a few private construction industries.

1.9 STUDY STRUCTURE

Chapter 1: Introduction

This chapter presented the background for BIM-T in the built environment. This chapter also served as an introduction to the rest of the dissertation. This chapter describes the research and includes the study's background and problem, research aims and objectives, research methods, constraints, assumptions, ethical concerns, delimitations, theoretical and conceptual framework, and lastly, the importance of the research.

Chapter 2: Literature Review

This chapter includes a structured critical evaluation of the literature on state-of-the-art BIM-T among construction professionals, verifying the degree of awareness, limiting barriers to BIM-T application, and the impact of BIM-T in the built environments of South Africa and Nigeria.

Chapter 3: Research Methodology

The methods used to attain the project's goals and objectives were presented in Chapter 3. It contains definitions and summaries of the research approach used. The chapter then explains the population and the sample taken from it. It also specifies how the information was analysed and presented to evaluate the data obtained.

Chapter 4: Data Analysis, Results Presentation, and Discussion: Addressing Issues in the South African Construction Industry.

This chapter begins by defining the research and presenting the results of the study conducted in South Africa. SPSS was used to analyse the data. The data collection and analysis were described. The results were presented theoretically and in a series of graphs and tables organised into parts obtained from the study and analysed in terms of the literature review and the prior chapter.

Chapter 5: Data Analysis, Results Presentation, and Discussion: Addressing Issues in the Nigerian Construction Industry.

This chapter begins by defining the research and the results of the study conducted in Nigeria. The Statistical Package for the Social Sciences (SPSS) version 27 software was used to analyse the data. The data collection process and analysis were described. The results were presented theoretically and in a series of graphs and tables organised into parts obtained from the study and analysed in terms of the literature review and the prior chapter.

Chapter 6: Comparative Analysis of BIM Technology Application in Building Construction and Maintenance Management in Nigeria and South Africa

This chapter compares the outcomes of the results presented in chapters 4 and 5 and discusses the differences, if any.

Chapter 7: Conclusions and Recommendations

This chapter presents the results and conclusions, tying them to the issue statement and research objectives under consideration. Following that, recommendations for implementation and more research options were presented.

CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

An extensive critical review of published academic articles focusing on state-of-the art of BIM technology including its level of awareness, usage, barriers, impact, benefit and strategies to would promote its application in developing regional built environments was discussed. This chapter further provides a general background to BIM-T knowledge in developing regions.

2.2 CONSTRUCTION INDUSTRY BACKGROUND

Construction in the ancient world depended on resources found within its environments, such as land, climate, and local collective skills, to create shelter forms that reflected a precise and detailed knowledge of local climatic conditions (Toyin *et al*., 2022). Also, a reasonable understanding of the available construction materials' performance characteristics is essential (Ngowi *et al*., 2005). Although the earliest settlements and shelters were constructed of mud, stone and forest materials, they protected against rain, wind, cold and other weather factors. The methods used to build these shelters from the materials described above evolved from several tries and mistakes, as well as the experience of generations of builders who continued to use what worked and reject what did not. Notwithstanding, construction was typically an endeavour that engaged the participation of community members in the development of their immediate communities. To date, people have participated in all stages of development, from planning to final production, and have been able to combine their ideas and themselves to symbolise their culture. For example, dwellings in ancient Greek communities surrounding the Mediterranean were composed of mud with a timber framework, while temples and theatres were eventually built of marble. However, these communities were captured by the Romans, who founded the Roman Empire, which affected the construction methods and the community's entire culture. At its apex, approximately the 2nd to the 1st centuries BC, the Roman Empire grew to approe him ximately 60-100 million people, expanding from Rome into what is now Great Britain and the Middle East (Cowan, 1987; Butnariu, 2020). Ngowi *et al*. (2005) reported that the "Romans developed remarkable infrastructure, and most buildings based on stone and marble…". Thus, construction technology advanced significantly in Rome, Ancient Egypt, China, and Greece. The Chinese imperial palaces, Greek temples, and Egyptian pyramids continue to amaze and inspire us today (Bárta, 2022). Imhotep, who flourished between 2650 and 2600 B.C. is often considered the first known architect and engineer (Bárta, 2022). Figure 2.1 shows the Egyptian pyramid (Djoser in Saqqara) constructed by Imhotep, which depicts the imaginary initiatives employed in construction back then.

Figure 2.1 Pyramid complex of Djoser in Saqqara (Egypt) (Source: Bárta, 2022)

2.2.1 Evolution of Construction

As more people moved to cities, the capacity and scope of development increased. Humans created more complex permanent structures to live, work, and socialise, as well as infrastructure allowing immobile living (Mewomo *et al*., 2022). These projects necessitated the use of engineers and architects, as well as construction and facility managers. Nevertheless, industries as we know them took shape in the 1600s. Engineering and architecture became recognised as different professions needing specialised training. Andrea Palladio (born in 1508 A.D.) is often regarded as the pioneer of modern architecture (Jones, 2022). Palladio created palaces and rural estates for the Italian aristocracy and was famous for his innovation and use of materials to meet his clients' demands. His work significantly impacted subsequent architects, especially his use of a conventional temple façade (Figure 2.2) as the most prominent roofed approach porch (Jones, 2022).

Figure 2.2 Prominent roofed approach porch (Source: Jones, 2022)

John Smeaton is known as the "Father of Civil Engineering". He is renowned for his bridges, roads, millworks and water projects. His most famous accomplishment is the Eddystone Lighthouse in Cornwall, England, one of the first to be built from interlocking stone. In addition, he established the Society of Civil Engineers, the world's first engineering society.

2.2.2 Contemporary Advancement of Construction

Construction continued to expand on the economies of scale established during the industrial revolution into the twentieth century. Skyscrapers were famous in the mid-twentieth century, notably in New York and Chicago. During the "first great period" of skyscrapers, a series of record-breaking skyscrapers were constructed. Each builder strived to surpass its predecessor, and firms considered the structures as expansions of their brand. New York became home to most of the world's largest and most famous buildings, including the Woolworth and Flatiron buildings. Contractors and engineers developed strategies to reduce building costs and schedules to make construction more effective during this period. The twenty-first century also saw a skyscraper race between Eastern and Middle Eastern countries. In 2003, the "Petronas Twin Towers" in Kuala Lumpur set the record for the tallest skyscraper outside of the United States. Dubai now holds the title: with the United Arab Emirates' 2 716-foot-tall Burj Khalifa (Jacob, 2021). Aside from the height, some of the most innovative skyscraper developers are "experimenting with architectural styles, innovative materials, energy-efficiency techniques, and occupant comfort" (Jones, 2022). Figure 2.3 shows the evolution of buildings over time.

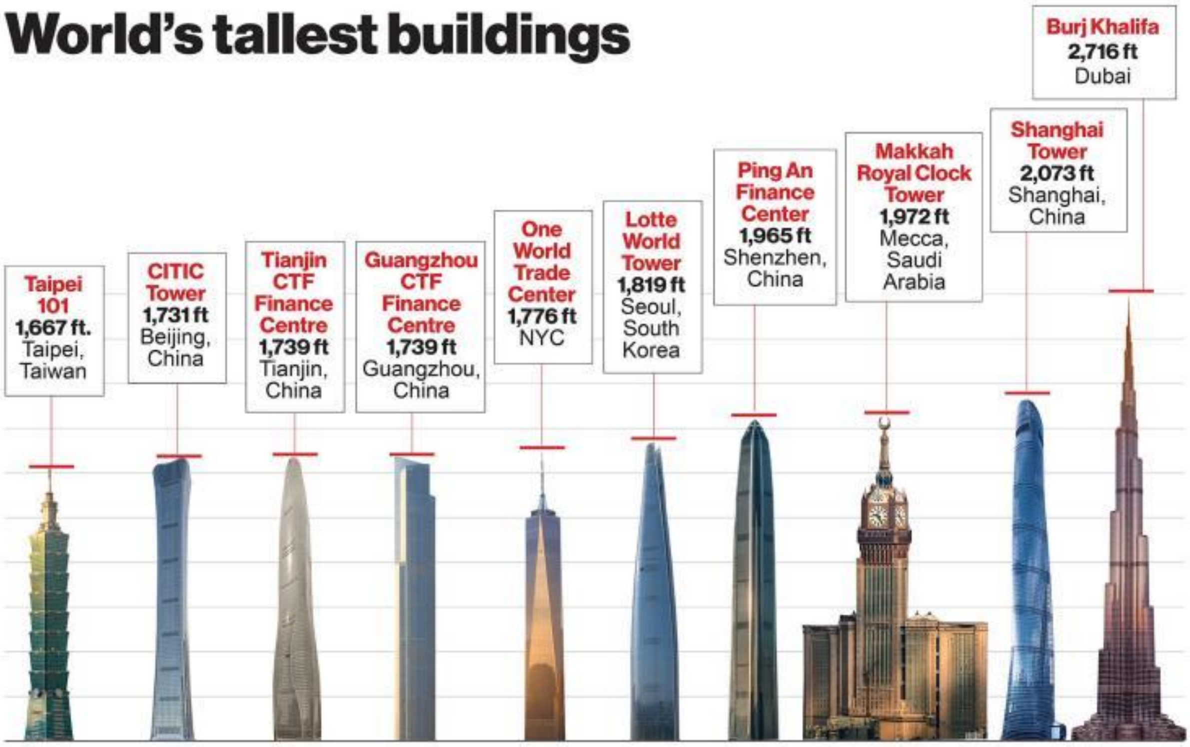


Figure 2.3 Evolution of buildings over time. (Jacob, 2021)

2.3 AFRICAN CONSTRUCTION INDUSTRY

The African construction industry's face is changing. Construction projects across the continent are increasing in size and sophistication. According to recent assessments, this is due to fast urbanisation, rapid economic growth, a growing middle class, and regional integration in many of Africa's 54 countries. These contribute to an ever-increasing demand in Africa's construction sector, as major infrastructure projects are underway across the continent. This trend raises several concerns for industry stakeholders, such as what is required for effective project management, which tasks have priority and how to access the African market, how to get finance for a project, and so on.

2.3.1 South African Construction Industry

Since the 1970s, foreign visitors to South Africa have marvelled over how ‘American’ the country’s larger cities seemed. Some had flown into Johannesburg and thus saw the town at the end of what will almost certainly turn out to be its final cycle of skyscraper building projects. These, set in a strictly defined group in the centre of the city, were the most superficial and potentially notable aspect of the Americanism identified by a knowledgeable arrival (Radford, 1998). The recently used qualifier was encouraged by the skyscraper core’s current ubiquitous character. Very few cities are currently without it, and it has thus become conventional in the late twentieth century. The skyscraper is generally recognised as an American creation, possibly the country’s most significant contribution to modern buildings and creating contemporary modernism (Radford, 1998).

Moreover, tall buildings first arose in Cape Town, then South Africa’s central city, in the mid-1890s. Shortly after, around 1902, Johannesburg saw a brief era of competition with the mother city. Both cities generate an embryonic vertical core of at most a half-dozen structures. Durban was not as active, although it established a smaller unit of its own (Radford, 1998). Presently, the Leonardo in Johannesburg, South Africa, is the tallest building in South Africa and also the tallest building in Africa at 234 m (768 ft) high and having 55 floors (Legacy 2023).

2.3.2 Nigerian Construction Industry

Environmental and cultural factors are not exempt from influencing Nigerian construction, during the same period. Nevertheless, Nigeria's style of construction reflected its residents' culture. Also, its environment influenced the type of construction. Presently, the building material revolution and innovative development have made available a wide range of materials. Thus, these materials (bricks, glass and tiles) are either imported or produced locally. However, “the Nigerian construction industry has tried to meet the world’s standards” (Calebella, 2022).

This advancement in the construction industry has caused a significant shift in the economy (Mewomo *et al*., 2021). It contributes 3-6% of the Nigerian GDP before the pandemic (Calebella, 2022). Building methods in Nigeria became structured in the 1930s (Mbamali and Okotie, 2012). Buildings existed before but were not organised (looking at codes or construction laws). From cave homes to skyscrapers (Mbamali and Okotie, 2012), buildings in Nigeria's construction industry have developed (Calebella, 2022; Mbamali and Okotie, 2012). Back in 1965, the Cocoa House in Ibadan, Oyo State, was the tallest building in Nigeria and the first skyscraper in West Africa at a height of 105 metres. Currently, the NECOM House is the tallest building in Nigeria and West Africa, from 1979 to date, with 32 floors and a height of 525 ft (160 m) (NECOM 2022).

2.4 AWARENESS AND USAGE LEVEL OF BIM TECHNOLOGY

BIM has lately gained popularity in the architecture, engineering, and construction (AEC) industries (Toyin and Mewomo, 2023; Cao *et al*., 2021). It can coordinate a project's design, analysis, and construction phases, increasing project dependability (Carvalho *et al*., 2021). BIM design and construction plans may be linked by connecting the building model to the project schedule; AEC professionals could use BIM to simulate each stage of the construction process and display a virtual representation of the building and site (Cao *et al*., 2021). Furthermore, it allows them to track, keep, and quickly update the digital records of completed tasks during the construction phase (Habte and Guyo, 2021; Toyin and Mewomo, 2022e). Subsequently, Quantity Surveyors can promptly generate accurate and reliable cost estimates through programmed quantity takeoffs from the building model (Mirarchi *et al*., 2020). These enable fast cost feedback on design changes (Fan, Wu, and Hun, 2015). It is also an efficient instrument to visualise progress and manage construction works (Lin, 2014; Toyin and Mewomo, 2023). The AEC's communication and discussion can be improved efficiently through visualisation during the construction phase (Habte and Guyo, 2021; Tezel *et al*., 2021; Zaini *et al*., 2020; Toyin and Mewomo, 2022c). Nevertheless, AEC can create additional management units, such as experience and knowledge management, which can be accommodated within the BIM platform.

Fan, Skibniewski and Hung (2014) conducted an extensive survey among contractors who have used BIM for their projects. It was reported that over 90% of the contractors claimed they were not willing to perform another project without BIM. This eagerness could be tagged to the real-life positive contribution and benefits realised with the help of BIM compared to the traditional construction method. The progress of BIM is still ongoing (Toyin and Mewomo, 2022b), and it has yet to realise its full potential in developing countries (Toyin and Mewomo, 2021; Toyin and Mewomo, 2023). BIM's evolution from a construction tool to a project management culture may be viewed as the steady development of a new collaborative team approach. The contribution of BIM during on-site construction is simply one sign of the BIM cultural revolution. Di Giuda *et al*. (2020) study reveals that with the help of BIM integration on the studied project at the school of Melzo, BIM enables adequate control of quantitative and geometric control, wherein it allows for verifying the positioning of the elements installed, dimensional correspondence, and fixing methods on-site.

2.5 BIM-T ADOPTION/APPLICATION BARRIERS

Despite a body of research and actual evidence demonstrating that BIM can improve the design, construction, operation, and maintenance of building construction works (Azhar *et al*., 2012; Arayici, 2015; Charef *et al*., 2019; Gamil and Rahman, 2019; Van Roy and Firdaus, 2020; Toyin and Mewomo, 2022b; Toyin and Mewomo, 2022c; Toyin and Mewomo, 2023), it has also been stated by several authors, including Sun *et al*. (2017); Saka and Chan (2020); Wu *et al*. (2021); Toyin and Mewomo (2021) and Toyin and Mewomo (2022a) noted that BIM technology deployment confronts numerous challenges that impede its widespread adoption/application on construction sites. This act makes BIM appear much more difficult to acquire and implement. They are viewed as modern phenomena that have the potential to disrupt the ways employed by the built-professional and construction industries to carry out their tasks. Whereas traditional design and construction management technologies cannot provide the accuracy demanded by the growing complexity of modern structures (Alemayehu *et al*., 2021, Toyin and Mewomo, 2021).

For decades, the construction industry has focused on BIM and various research projects have investigated BIM acceptance and implementation hurdles. This demonstrates that the industry is eager to change present methods (Alemayehu *et al*., 2021).

Regardless, there is a need to document the barriers to BIM application during the construction phase of a building project (Toyin and Mewomo, 2022a). Ahmed (2018) undertook a broad examination of the challenges to BIM implementation. The author found 37 impediments. According to the author, the key challenges are social and habitual resistance to change, outdated contracting methods, training fees and a steep learning curve, high software acquisition costs and a lack of understanding regarding BIM. These studies highlight the BIM obstacles in the construction industry.

Nevertheless, the critical review on BIM adoption/application conducted by Toyin and Mewomo (2021) recorded 57 barriers across the developed and developing regions. As a result, the study by Toyin and Mewomo (2022a) grouped the 57 barriers into two categories: developing and developed countries.

The grouping criteria are as follows: low- and middle-income economies (developing countries), whereas upper-middle- and high-income economies (developed countries) (IMF 2021). Moreover, 33 barriers fall within developing countries, thus being used for this study.

2.5.1 Summary of the Literature Review Findings

From the findings of the author as published in Toyin and Mewomo (2021; 2022a), 33 barriers were revealed to be unique to developing countries, as shown in Table 2.1. Since Nigeria and South Africa fall within the developing countries categories, thus the barriers were investigated among the professionals.

Table 2.1 Barriers to BIM application in developing countries

S/N	CODE	BARRIERS	REFRENCES
1.	BC1	Low computer skills among some professionals	(Toyin and Mewomo, 2022c, Toyin and Mewomo, 2022a, Olanrewaju *et al*., 2022, Wu *et al*., 2021, Tran-Hoang-Minh *et al*., 2021, Toyin and Mewomo, 2021, Shin and Kim, 2021, Saka and Chan, 2021, Leśniak *et al*., 2021, El Hajj *et al*., 2021, Durdyev *et al*., 2021, Bouhmoud and Loudyi, 2021, Alemayehu *et al*., 2021, Van Roy and Firdaus, 2020, Saka and Chan, 2020, Olanrewaju *et al*., 2020, Deng *et al*.,
2.	BC2	Lack of familiarity with BIM capacity	
3.	BC3	Habitual resistance to change from the traditional style of design and build.	
4.	BC4	Poor awareness of BIM benefits.	
5.	BC5	Misunderstanding the BIM concept.	
6.	BC6	Lack of support from senior leaders of the construction industry from the traditional contracting system to embrace the use of BIM technology.	
7.	BC7	Lack of well-develop practical strategies and standards.	
8.	BC8	Project risks caused by BIM.	
9.	BC9	Lack of support from owners and managers due to inadequate knowledge of BIM concepts.	
10.	BC10	Negative Attitude towards Working Collaborative.	
11.	BC11	Lack of a Stable BIM tool Working environment.	
12.	BC12	Lack of motivation to implement BIM in projects.	
13.	BC13	Inaccessibility to genuine BIM tools.	
14.	BC14	Absence of adequate quantifiable digital design information.	
15.	BC15	Difficulties with required training time.	
16.	BC16	Inadequate BIM data.	
17.	BC17	Complex process of learning BIM technology.	

S/N	CODE	BARRIERS	REFRENCES
18.	BC18	Complexity in getting used to BIM technology and procedure.	2020, Zhou, Yanfg and Yang, 2019, Tan *et al*., 2019, Mtya and Windapo, 2019, Hamma-adama and Kouider, 2019, Chan *et al*., 2019, Ahmed, 2018, Kekana *et al*., 2014).
19.	BC19	Lack of BIM experts.	
20.	BC20	Reluctancy/lack of knowledge sharing by firms that have successfully implemented BIM.	
21.	BC21	Lack of organised BIM studying means.	
22.	BC22	BIM consulting market is confused.	
23.	BC23	High costs related to the BIM software, hardware, and training.	
24.	BC24	Project planning costs increased.	
25.	BC25	Cost of BIM experts and Time required for training.	
26.	BC26	Government's unwillingness to support BIM use.	
27.	BC27	Missing insurance framework for BIM application.	
28.	BC28	Lack of protocols in line with market demand.	
29.	BC29	Unclear sole ownership right of BIM tool data.	
30.	BC30	Contractual BIM environment.	
31.	BC31	Absence of insurance applicable to BIM application.	
32.	BC32	Low knowledge about BIM application principles and guidelines for certain project professionals.	
33.	BC33	Absence of support from policymakers.	

2.6 BENEFITS DERIVED FROM BIM USE

In their research, Lu *et al*. (2013) create a model to measure BIM benefits in construction. The authors noted that BIM offers both practical and academic values, including enhancing project management activities, improving people's understanding of BIM, and helping to rationalise their investment in it. The authors' findings justified the capacity of BIM in academic settings, value for money, and managerial activities. Moreno *et al*. (2014) researched the perceived benefit of using BIM to design and construct educational facilities. The authors find that BIM use increases client engagement, clarifies the design, serves as a new marketing tool for firms, and improves collaboration and communication amongst professionals (Toyin and Mewomo, 2022d). In addition, it lowers risk and better predicts outcomes due to discovering errors, omissions, and conflicts before construction and automation of documentation (Toyin and

Mewomo, 2023). Dowsett and Harty (2019) studied the link between BIM benefits and implementation" by focusing on two case studies. The benefits of using BIM derived from the case study are: "automation of manual processes, improved understanding of design intent, and improved consultation meetings." Nepal, Jupp and Aibinu's (2014) research also focused on two documented case studies of BIM implementation. In both case studies, BIM benefits were reported and grouped under "benefits to the owner" and "benefits to general contractor and sub-contractors." From the real-life case examined, it was realised that BIM implementation on these projects adds fantastic value and benefits in the interest of the client and contractor. Evidence proved that understanding these benefits will encourage the parties to adopt BIM in their next project.

Lu *et al.'s* (2015) research focuses on construction projects. The authors compared the project with real-life BIM and non-BIM projects based on "time-effort distribution curves" at the design and building production stages. The findings show that BIM use enhances the project design phase by reducing time spent on the design. Compared to those without BIM, it improves design efficiency and makes it easier to conduct quantity surveying. Enshassi and AbuHamra (2017) conducted research in Palestine and noted that BIM use "can reduce project duration time, cost and enhance project quality." This finding agrees with the findings of Ismail *et al.* (2019). Babatunde *et al.*'s (2018) research in Nigeria identified 14 benefits derived from using BIM. Information was elicited from the perspectives of academia and students, focusing on two selected universities offering Quantity Surveying. These benefits reported are not well actualised in the country as the government and the lawmakers are yet to incorporate BIM in the building code of the country, as recently suggested by Toyin and Mewomo (2022a).

Enshassi *et al.* (2018) studied the benefits of BIM in the Palestine Gaza Strip construction industry. The authors identified 19 benefits derived from using BIM in the country, which were further classified into four groups. According to the findings, the essential separate BIM benefits amongst four major elements are increasing coordination between contract parties, improving building management and operation, controlling total life cycle cost, reducing change orders, improving building management and operation, the decision-making process, communication, safety, and quality. These findings are in tandem with various authors' assumptions about BIM benefits; this makes the results valid and buttresses more validation of BIM capacities. Hosseini *et al*. (2018) researched the need for BIM for an existing building. The authors clarified that there are numerous benefits to BIM use in an existing building. These could not be achieved due to some barriers hindering BIM adoption. Toyin and Mewomo (2021) documented these barriers in a broader review. The authors established that this barrier had caused a setback in realising BIM benefits. Ahankoob *et al*.'s (2021) study in Australia elicited information from experienced BIM users in Queensland's building industry. The findings show that their experience with BIM use directly influences their ability to judge BIM's capacity based on its possible benefits and 14 crucial BIM benefits were identified. The survey findings reveal that as building contractors in the country become more experienced in using BIM, their understanding of the business values realised with BIM use improves. Jin *et al*. (2017) and Yang and Chou's (2019) study documented the following highly ranked benefits of BIM: providing new working areas, reducing rework, errors and omissions, and enhancing project quality and cost control. According to experts in the China AEC industry, these were rated mostly from developed regions where BIM is used.

Similar research was recently conducted by Liu *et al*. (2019) the study focuses on professional perceptions of BIM. The practising professionals in Chongqing, China, were contacted and 13 possible benefits were identified while using BIM. The top-ranked benefits were in line with the previous study by Liu *et al*. (2019). Okakpu *et al*.'s (2019) study focused on a real-life case study. The author used agent-based simulation modelling for the refurbishment of the building project. They concluded that the "BIM network model was almost a hundred percent effective in reducing errors or project uncertainties" and showed significant improvement in the performance of the project network.

Yang and Chou's (2019) research focuses on BIM benefit evaluation. The authors designed an overall BIM benefit evaluation structure for its implementation through the evaluation of BIM project-based derived benefits. Seven (7) benefits were identified on the basis of which the subjective BIM benefit evaluation model was developed. Al-Ashmori *et al*. (2020) studied the benefits of BIM and its influence on BIM implementation in Malaysia. The authors noted seven (7) essential benefits of encouraging Malaysian construction companies to implement BIM. Al-Ashmori *et al*.'s (2020) research on 4D-BIM adoption focused on the Indian construction industry. The following were identified as the most realised benefits of 4D-BIM by the authors: communicating the construction plan, simulating time schedules, and visualising the construction flow. These are the most appreciated benefits of BIM in the 4D context of Indian construction.

Habib (2020) researched the 6D-BIM model to assess its features in building sustainability. The authors identified seven (7) crucial benefits accruable with 6D-BIM. Sanchez *et al*. (2016); Vimonsatit and Foo (2015), and Musa *et al*. (2019) studied the benefits of BIM integration in building production projects from the design stage to the construction stage. The expected benefits derived from BIM are time management, clash detection, easy taking-off, resource and data management, easy communication, and collaboration among professionals.

Shibani *et al*.'s (2020) research on the Iraq construction industry focused on the benefits of adopting BIM in small and medium enterprises in the country. The study identified five main important benefits derived from using BIM in Iraq. According to Malzoor et al. (2021), the following critical benefits have compelled Malaysian organisations to use BIM in their projects: increased productivity and design efficiency; reduced time and cost associated with design change; integrated construction scheduling and planning; elimination of clashes in design; improvement in multi-party communication and synchronization of communication; monitoring and tracking of progress during construction, and the identification of time-based clashes.

Brito *et al*.'s (2021) study noted the following benefits of implementing BIM in a construction project: favourable cost-benefits, waste control and a realistic completion time. Yuqi and Jiajia's (2018) and Hong *et al*.'s (2020) studies focused on the benefits of BIM applications. The authors reported that the application of BIM can improve decision-making, enhance the sustainability of buildings; reduce engineering conflicts, save resources, reduce design and construction changes and help manage cost control. The contributions of the various authors established a clear road map for this study.

2.7 IMPACT OF SUCCESSFUL BIM TECHNOLOGY APPLICATION

BIM comprises three essential characteristics. The first aspect is that the model's data and information can be saved in the BIM databases to make collaboration easier (Sinaga and Husin, 2021; Rodrigues and Lindhard, 2021; Toyin and Mewomo, 2022d). The second characteristic enables control of the database updates, such that a database change impacts fundamental aspects of the model (Habte and Guyo, 2021; Duarte-Vidal *et al*., 2021). Thirdly, industry-specific applications allow model information to be stored for future reference (Vanlande *et al*.; 2008, Bouhmoud and Loudyi, 2021).

2.7.1 BIM-based Construction vs Conventional Mode

It is necessary to compare BIM-based construction and contracting methods with traditional methods to determine the impact of BIM adoption. Parvan (2012) classified the BIM package based on three critical necessary technologies: 3D-CAD technology, object-oriented technology, and parametric modelling technology. Furthermore, the combination of these technologies creates an outstanding BIM-based platform. These enable the production of effective data management, enhanced modification management and increased interoperability for BIM technology tool managers. Nevertheless, 3D-CAD technology generates a collaborative virtual working environment based on a structured 3D model. Thus, the drawing objects of CAD technology are the virtual model component of the 3D model. Even though the drawing objects were scraped, they are now transformed into object-oriented technology. As a result, those items are now captured like architectural and engineering design objects such as walls, doors, floors, beams, pipelines, windows, roofs, and so on. In virtual object-oriented technology, objects are the essential additional modelling objects.

2.7.2 BIM Impact Classification on Construction

The BIM impact discovered in the literature was further classified depending on the phases of the building and maintenance lifecycles. These stages include the "conception phase, design phase, pre-construction phase, procurement phase, post-construction phase, maintenance phase, and demolition phase" (Hoang *et al*., 2020; Toyin and Mewomo, 2023).

2.7.2.1 Conception phase

The conception phase of a building construction project is related to project planning and development. This is the start of the construction process. The brief for the project or facility that will be developed is created by the customer. This step entails identifying a project plot of land, appointing an architect or other required construction consulting expert and producing an early concept of pre-designs. (Succar *et al*., 2012; Clevenger *et al*., 2014; Al-Ashmori *et al*., 2020; Toyin and Mewomo, 2022b). This stage is critical since it will decide the project's success in terms of client satisfaction. As a result, proper precautions must be taken to ensure a satisfactory conclusion as work progresses. According to researchers, BIM technology positively influences this phase (Chen, John, and Cox, 2018b; Fernandes, 2013; Muñoz and Arayici, 2015; Crippa *et al*., 2020). These aid in the pre-design of the client briefing.

2.7.2.2 Design phase

The design phase is when the client's dreams meet what is feasible. The client's ambitions and dreams should not be overlooked while creating various designs or concepts (Toyin and Mewomo, 2023). In addition, the completed 3D design of the project will be visible, and a design model can be produced upon request. When BIM technology is used successfully in a project, it can improve design quality and efficiency, boost design self-confidence, and eliminate/reduce design mistakes (Doumbouya *et al*., 2016; Smits *et al*., 2017; McAuley *et al*., 2012; Becerik-Gerber and Rice, 2010; Toyin and Mewomo, 2023).

2.7.2.3 Pre-construction phase

The pre-construction phase is primarily concerned with preparing to begin the project, finalising the design, developing strategic plans to carry out the project, and organising the project management team. In this phase, the BIM application aids in effective work scheduling, eliminates design disagreements among built environment professionals and contractors, and discovers design discrepancies and omissions supporting construction and project management (Akintoye *et al*., 2012; Ahankoob *et al*., 2018; Crippa *et al*., 2020; Mesároš *et al*., 2020).

2.7.2.4 Procurement phase

This stage concerns purchasing or renting materials, tools, equipment, machinery, and other items essential for the project's development. BIM-T simplifies the scheduling of materials and labour for each stage of construction, lowering total project costs and enhancing return on investment for the customer and contractor (Shen and Issa, 2010; Parvan, 2012; Olawumi and Chan, 2018; Crippa *et al*., 2020).

2.7.2.5 Construction phase

The building construction phase is concerned with transforming paper or various CAD plans into actual reality. This stage has the most focused task; those activities have deadlines or milestone dates for each building grouping part. BIM has a significant impact in this phase. It improves construction scheduling and planning, enhances work efficiency and safety, improves day-to-day work progress, facilitates tracking of construction activities, enhances project speed and saves time (lessening the time for routine data gathering and recording), lowers the risks and costs incurred by contractors and subcontractors in a project, improves the readiness for emergency events and improves construction management qualifications in terms of early collaboration (Li *et al*., 2014; Muñoz and Arayici, 2015; Linderoth *et al*., 2020; Hoang *et al*., 2020; Crowther and Ajayi, 2021).

2.7.2.6 Post-construction phase

In this phase, the project has been completed and now at the post-construction phase. This is where the final checklist of all correctly completed work will be reviewed and signed off by the relevant building professional(s). The purpose of the check is to ensure that it complies with all of the design papers. As a result, the expert will provide a certificate of substantial completion. The client can then move in after that. At this point, the BIM application will improve proactive maintenance scheduling and deliver it to the client (Olawumi and Chan, 2018; Doumbouya *et al*., 2016; Li *et al*., 2014; Azhar, 2011).

2.8 STRATEGIES TO PROMOTE BIM-T APPLICATION

Since BIM is accepted globally in the construction industry, developing countries such as South Africa and Nigeria must quickly realise the technology in order to not be left out of the revolution in the construction industry. As a result, it must accelerate its implementation. These issues raise questions about establishing measures to encourage BIM-T adoption in the building sector. Furthermore, the BIM application allows construction experts to combine project-based relationships and network structures, as well as project expectations and results, to increase performance, improve construction professionals' skills and competencies, and adapt to a new way of working. (Cao *et al*., 2017; Toyin and Mewomo, 2023).

The application of BIM in the construction industry will provide the best means to assure quality work and worker efficiency, alter intra- and inter-organisational connections and settings, and increase the global competitiveness of indigenous construction companies. The BIM application will modify the project team members' roles, duties, authority, interests and tasks (Toyin and Mewomo, 2023). The use of BIM in construction projects will dramatically change the construction process and its operations, as well as project design, project information development, and project delivery systems (Liao and Ai Lin Teo, 2018). BIM will allow building professionals to combine project-based connections and network structures, achieve higher performance, improve construction professionals' skills and competencies, and adapt to a new way of working (Cao, Li, Wang & Huang , 2017).

Much research has lately sought to construct and study BIM implementation strategies that would be effective and suitable for promoting BIM adoption. These studies address BIM implementation methodologies for various BIM adoptions (Lindblad and Guerrero, 2020; Zhou, Yang and Yang, 2019; Ma *et al*., 2020; Besné *et al*., 2021). To some extent, BIM application/implementation strategies have been projected or researched in countries including

South Africa (Odubiyi *et al*., 2019), Taiwan (Yang and Chou, 2018), Brazil (Junior *et al*., 2020), China (Herr and Fischer, 2019), Singapore (Oo, 2014; Liao and Ai Lin Teo, 2018) and Sweden (Lindblad and Guerrero, 2020).

Puolitaival and Forsythe (2016) report on BIM application strategies such as BIM training, BIM guidelines, networks and communication, and BIM project examples. As BIM application strategies for increasing BIM implementation in Malaysia, Azam Haron *et al*. (2015) noted the need to form a BIM task force, increase BIM awareness in the construction sector and publish national BIM guidelines (Odubiyi *et al*., 2019).

For various reasons, it is crucial to seek the opinion of the construction professionals on the most effective way to strategise an acceptable means of applying BIM in the construction industry. Firstly, scholars suggested that several impediments to implementing BIM must be overcome before reliable and realistic BIM acceptance can be accomplished in developing countries (Liao and Teo, 2019; Saka and Chan, 2020; Toyin and Mewomo, 2021). Secondly, it is necessary to limit the consequences of BIM adoption on construction activities, management needs, characteristics and relationships (Ahuja *et al*., 2020). Thirdly, robust BIM application strategies are required to grant the appropriate assistance, policies, tactics, incentives, legitimacy, resources and standards to enhance BIM application (Vidalakis *et al*., 2011). Lastly, successful BIM application methods must address the construction industry's growth, construction companies' economic growth, and construction organisations' capacity improvement.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 INTRODUCTION

This section clarifies the research paradigm, philosophy, methods, ethics, and research design employed in the study. This section further provides information on documents that enhance the research process from formulation of the study questionnaire to distribution, retrieval and methods employed in the analysis of the research findings. Figure 3.1 shows the schematic methodological approach used to formulate and analyse the research objectives. From Figure 3.1, an extensive literature review was conducted form which relevant secondary data was retrieved to formulate the survey questionnaire. The received valid survey data where then analysed and discussed, thereafter conclusions were drawn and substantial recommendation were followed.

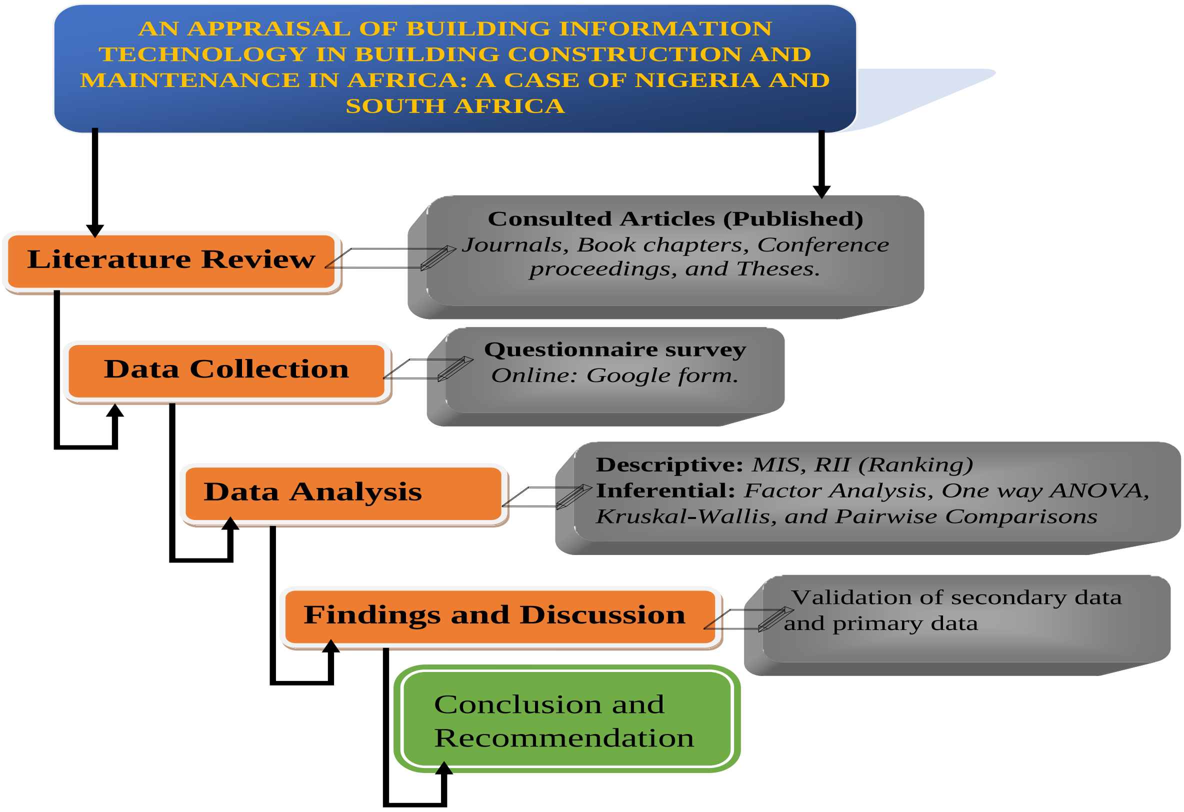


Figure 3.1 Research Methodology

3.2 PHILOSOPHY OF THE RESEARCH

The research's philosophical perspective must encompass a philosophical research approach, research paradigm, and research design approach (Al-Ababneh, 2020). The philosophical approach to research shows the idea for outlining the methodological approach to achieving educational research aims and objectives (Al-Ababneh, 2020). There are two main philosophical approaches: epistemology and ontology (Aliyu *et al*., 2015; Al-Ababneh, 2020). The authors see epistemology as the theory of knowledge interwoven with theoretical perspective and technique. Thus, philosophical analysis allows us to understand reality. While ontology is a philosophical study that concentrates on the study of reality,nature or existence (Kant, 2014). According to Aliyu *et al*. (2015), ontology is a compendium of terminology for describing knowledge or categorising items supposed to occur in a field of interest.

Similarly, Salama (2019) opined that ontology concerns the social, physical, and technical support that knowledge is built on and interacts with. The authors further recognised ontological positions such as idealism, which maintains that the external world consists only of appearances; objectivism or realism, which holds that the external world consists of natural and social existence; and relativism, which holds that the external world is a social construct. However, the definition by Aliyu *et al*. (2015); Holt and Goulding (2014); Kant (2014) and Salama (2019) has established limits for comprehending educational research's philosophical perspective. These formulations make it evident that ontology "concerns what is known", but epistemology "concerns how we understand what is known". This indicates that the ontological perspective of research is required for the epistemological stance of research. In addition, one more critical element of the philosophical foundation is the research paradigm; the philosophical inquiry concept adopts an accepted methodological technique. (Johnson and Christensen, 2019). Moreover, the research paradigms that grant the methodology for philosophical investigations are: “pragmatism, subjectivism, interpretivism, critical theory, functionalism, conflict paradigm, Neo-Marxism, naturalism, Marxism, post-modernism and existentialism” (Sim, 2019; Therborn, 2018; and Müller-Doohm, 2017). The research approach is the final phase of the philosophical basis. The research strategy has been defined as a collection of processes and strategies for comprehending and interpreting research problems or phenomena of inquiry within a specific philosophical enquiry (Al-Ababneh, 2020; Müller-Doohm, 2017).

According to Al-Ababneh (2020); Aliyu *et al*. (2015) and Salama (2019), there are three fundamental approaches to research: positivism, which asserts “that knowledge is formed through observation, facts, reason and evidence” based on the experience of senses and can be obtained by observation and experiment; post-positivism, maintains “that knowledge is shaped from testing propositions” and constructivism, asserts that “knowledge is formed by constructing meaning for it via investigation and understanding”. As a result, the philosophical position supporting this research in this study includes empiricism (the epistemological position), realism (the ontological position), and positivism (the research approach), as seen in Figure 3.2.

The ontological opinion deals with the nature and form of the phenomenon under investigation; therefore, this study investigates the extent to which BIM-T is used in building construction and building maintenance management in developing regions through the reasoning (realism) and experience of built environment professionals in Nigeria and South Africa. The epistemological position is based on knowing the phenomenon under study. Thus, this study highlighted empirical evidence (empiricism) as crucial in understanding the status of BIM application in the building production lifecycle among the direct participants of built environment professionals in Nigeria and South Africa. The study's methodological approach focuses on conceptualising the topic under investigation.

Axiology is known as the values of the research process; “positivities relies mainly on objectivity and so dismisses the importance of individuals’ subjective experiences and values—be they the experiences and values of research participants or researchers” (Park, Konge & Artino, 2020). For this study, the researcher did not have a direct relationship with the respondents, and the educational staff of the organisation mainly distributed the questionnaire. The research strategy is a technique and methodology that comprises broad assumptions and specific methods for data collection, analysis, and interpretation. As a result, it depends on the nature of the study topic, and aims and objectives under investigation. Table 3.1 shows the methodology adopted for each kind of philosophical approach. Since this study is positivist in nature, and adopts quantitative analytical tools to provide a result for the data generated.

Table 3.1 Philosophy Methodological approach

	Research approach	**Ontology**	**Axiology**	**Research strategy**
Positivism	Deductive	Objective	Value-free	Quantitative
Interpretivism	Inductive	Subjective	Biased	Qualitative
Pragmatism	Deductive/Inductive	Objective or subjective	Value-free/biased	Qualitative and/or quantitative

Source: Author findings

Figure 3.2 Philosophical approach and position for the research. Scorce: (Author findings 2022)

Positivism is a view that takes responsibility for the development of quantitative methodology; this approach entails collecting scientific data that is exact and based on measurement and is frequently analysed using statistics with the goal of generalisability (Park, Konge & Artino, 2020). Panhwar, Ansari, and Shah (2017) define positivism as a quick, straight, and succinct presentation rather than a long tale based on human emotions or subjective interpretation. Because of the value-free logic, it does not allow for any interpretation. The investigation includes and applies specific concepts or fundamental principles to the subject of inquiry (Park, Konge & Artino, 2020).

3.3 RESEARCH NATURE

The nature of this study allows for a systematised approach that directs the research toward achieving the research aims and objectives. The study's nature might be one or a combination of two or more strategies known as "exploratory, explanatory, and descriptive" analysis (Pallant, 2020; Kumar, 2018). Because this study employs the philosophical paradigm components, the research study's objective is both descriptive and explanatory. An explanatory research study strategy aims to establish a precise theory that may be used to define practical generalisation. Descriptive research answers questions that mostly start with the "who, what, where, when, and how" of the research study topic and questions. However, this study investigates the extent to which BIM technology is used in the construction industry, with special attention paid to the building professionals in Nigeria and South Africa. This entails eliciting data from them through a semi-structured and structured questionnaire, which will require an explanatory and descriptive strategy that aims to review the state-of-the-art of technology usage among the professionals.

3.4 RESEARCH DESIGN AND DATA COLLECTION

The research design, according to Joseph (2004), is the general method that you adopt to combine varied components of the study cohesively and logically to answer the research challenge. This is also the data collection, measurement, and analysis strategies. The parts of a research design include the investigation's logical structure and the aim of the data analysis.

3.4.1 Quantitative Research

Fellows and Liu (2021) see quantitative research as the methodological approach aiming to collect factual data to investigate the link between facts, ideas, and previous work. Leedy and Ormrod (2019) corroborate this by stating quantitative research answers questions regarding variables to predict, explain, and manage occurrences. However, quantitative research necessitates discipline and patience throughout the planning and design stages. Although technological difficulties may be encountered when collecting data, they can easily be managed. The work of data gathering and writing up is largely, but not totally, influenced by how the research was designed (Fellows and Liu, 2021; Mills and Gay, 2019). For this study, a quantitative analysis approach was adopted to address the research questions, starting with collecting and analysing the quantitative data. The quantitative approach involves the study of the relationship between different variables and how to generalise the results to a whole group

3.4.2 Primary Data Sources

This study's primary data is first-hand information elicited directly from the targeted respondents using a questionnaire. Nevertheless, questionnaires could take several forms, such as paper-and-pen based ones in which the respondent fills out paper forms. A web-based questionnaire is an electronic means of inviting respondents to complete the questionnaire to the best of their knowledge and ability. It is a more accurate form of generating quantitative data. The system automatically stores the generated data and information, thus creating Excel spreadsheets, which it can be imported directly to any analysis software, unlike the paper-and-pen based data that require rigorous codings before analysis can be done.

3.4.3 Secondary Data Sources

Secondary data for this study were acquired from various scientific databases such as Web of Science, Scopus and Crossref, which contain journal articles, books, conference papers and theses, and both local and international institutional repositories. The information was sought through the Durban University of Technology (DUT) library. Figure 3.3 explains the flow chart process involved in the execution of this research. The primary data retrieved were critically reviewed; this shows the extent and limitations of previous research, as well as enabling the selection of this study’s variables that will form the questionnaire.

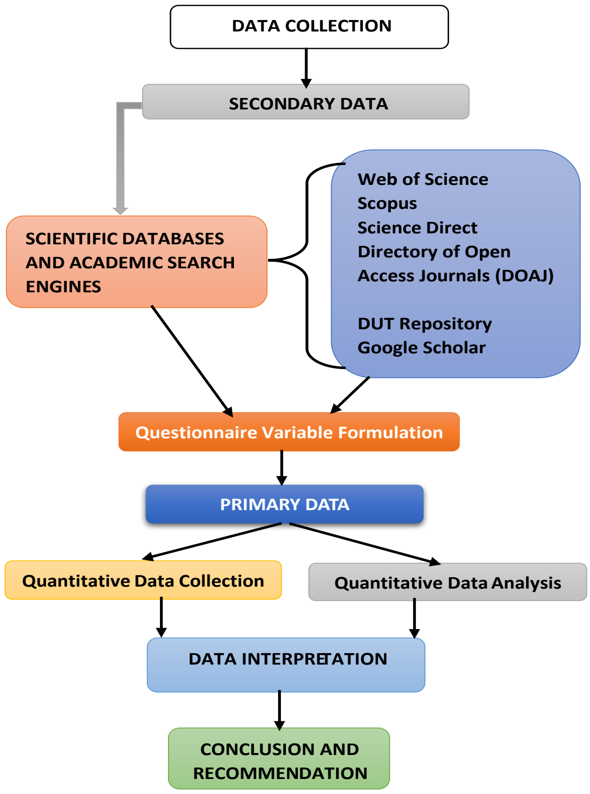
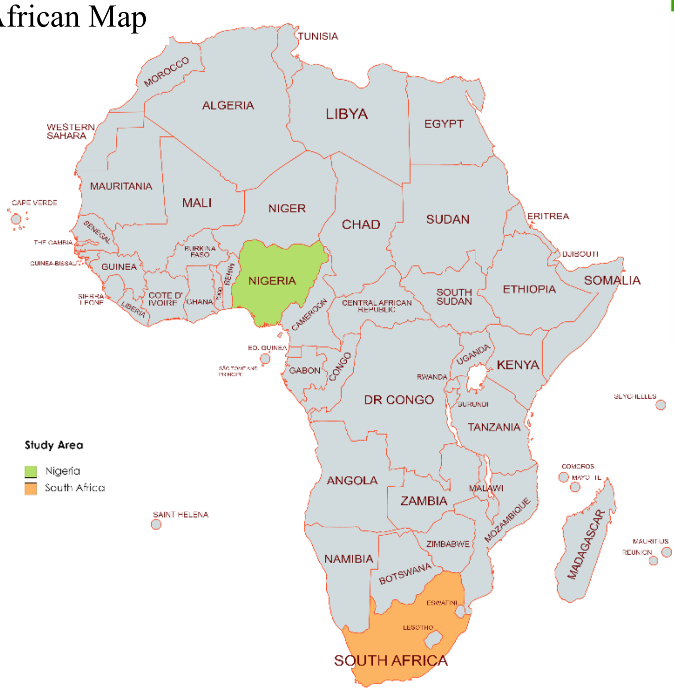


Figure 3.3 Research design flowchart. Source: (Author 2022)

3.5 THE STUDY AREA

The study plan involves target and accessible sample populations. As previously outlined, the target populations for this study comprise SACPCMP in South Africa and Nigerian built environment registered professionals in Lagos (Architect, Builders, Engineers and Quantity Surveyors). SACPCMP is the professional body of registered professionals in South Africa. While in Nigeria, each professional has its own governing and monitoring professional bodies body, for instance, The Nigerian Institute of Architects (NIA); The Nigerian Institute of Building (NIOB); The Nigerian Society of Engineers (NSE) and The Nigerian Institute of Quantity Surveyor (NIQS). All these professional members took part in the research. Figure 3.4 shows the location of the study area on the map of Africa.

African Map



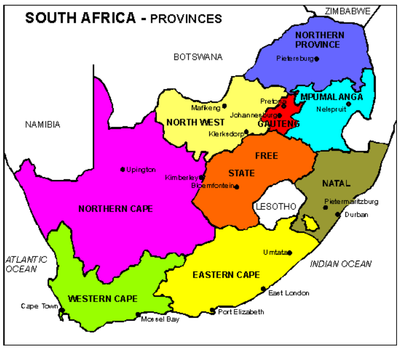


Figure 3.4 study area

3.5.1 Sampling Technique

Alvi (2016) views sampling and selection procedures as the means of selecting the participants that form the sample size. The study sample comprises accessible participants from the research population. The sampling frame is a list of all the individuals in the research population who may be contacted and from whom the sample size is calculated (Ishak and Abu Bakar, 2014). In this study, purposive sampling was employed. Purposive sampling is a non-probability sampling technique, where respondents are sampled based on pre-determined criteria or characteristics (Korstjens and Moser, 2018). Purposive sampling allows for the selection of individuals who can share information about an event or phenomenon under study. The procedure includes selecting individuals with the necessary traits and expertise from previous projects, forming large samples that match the profile of the research population, and collecting reliable and comprehensive information from study participants (Etikan, Musa and Alkassim, 2016).

3.5 2 Target Population

The target population for this research is the registered built environment professionals to whom the research is related and from whom systematic data and conclusions can be drawn in South Africa and Nigeria. The target respondents, as previously defined, are the built environment professionals who are primarily involved in the building construction, management, and maintenance of building facilities in both countries.

3.5.3 Sampling Size

Due to the impracticability of sampling every person in the target population, a considerable number representing the entire population was adopted. To achieve this study's sample size the following formula proposed by Yamane (1973) was used:

$$n = \frac{N}{1 + N(e^2)} \quad \textit{Equation 3.1}$$

where n = sample size

N = Number of the target population

e = precision/error limit = 10%

The results yielded by Yamane's (1973) formula are tabulated in Table 3.2.

Table 3.2 Population size and sample size

Professionals	Population Size (PS)	Sample Size (SS)	Total		Valid sample received	
			PS	SS	South Africa	Nigeria
SACPCMP	2,720	97	2,720	97	101	
NIA	958	91	5,108	363		272 75% of 363
NIOB	610	86				
NIQS	870	90				
NSE	2,670	96				

3.5.4 Questionnaire Design

The process of developing the questions and structure of a survey instrument (questionnaire) for data collection is referred to as questionnaire design (Artino Jr *et al*., 2014). The process aims to gather consistent data while minimising standard errors in data analysis (Brace, 2018; Kent, 2020). The survey instrument for this study consists of a series of written, open-ended questions with some possible answers. The importance of each question was determined by its contribution to the study objectives, the necessity for answer cross-checking, the need to collect non-ambiguous responses, and the need to elicit correct and relevant information. The survey instrument was divided into six (6) components, the first of which covered the demographic characteristics of the respondents. Sections 2 to 6 address research objectives 1 to 5. Table 3.3 summarises the layout of the questionnaire.

Table 3.3 Summary of the survey questionnaire design

SECTIONS	Questions asked	Type of scale used: Likert
1. Background Information	Gender, Level of education, indicate your profession, Years of professional experience	Please note that your response will remain anonymous. Your co-operation is appreciated.
2. Level of awareness and Usage of BIM	Are you aware of BIM? The phase of applying BIM How long have you been using BIM? BIM awareness Level of BIM tool usage Stages involved in Building production Use of BIM for maintenance	5-point scale where: 1= Never Use; 2= Very Low; 3= low; 4= High; 5= Very High
3. Barriers hindering the application of BIM	Low computer skills among some construction professionals Lack of familiarity with BIM capacity…	5-point scale where: 1=strongly disagree; 2= disagree; 3= neutral; 4= agree; 5= strongly agree.
4. The benefit derived from using BIM	Increase digital representation Allow linking of…	
5. Impact of successful BIM application	Improve ROI Improved quality design and productivity…	
6. Strategies to promote BIM		In your own opinion, kindly suggest strategies that can be used to promote BIM-T application among built environment professionals in your Country toward the sustainability of building construction and maintenance.

3.6 METHOD OF DATA ANALYSIS

Data analysis was conducted using the primary data gathered from the survey. The Statistical Package for the Social Sciences (SPSS) version 27 software was used to analyse the data collected during the research. Table 3.4 reveals the type of analysis used for each objective.

Table 3.4 Summary of the survey questionnaire design

Objective (OBJ)	Method of data gathering	Type of analysis conducted
OBJ 1: BIM level of awareness and usage	A structured questionnaire (closed-ended) web-based	Descriptive statistics: Mean, RII and Ranking Inferential: ONE-WAY ANOVA Result presentation: Tables, Figures and charts.
OBJ 2: Barriers hindering the adoption and application of BIM	A structured questionnaire (closed-ended) web-based	Descriptive statistics: Mean, RII and Ranking Inferential: PCA Result presentation: Tables, Figures and charts.
OBJ 3: Benefits of using BIM in the construction and maintenance of building projects	A structured questionnaire (closed-ended) web-based	Descriptive statistics: Mean, RII and Ranking Inferential: Kruskal-Wallis test and Pairwise comparisons Result presentation: Tables, Figures and charts.
OBJ 4: Impacts of BIM-T application	A structured questionnaire (closed-ended) web-based	Descriptive statistics: Mean, RII and Ranking Inferential: PCA Result presentation: Tables, Figures and charts.
OBJ 5: Strategies to promote BIM-T application	A structured questionnaire (open-ended) web-based	Descriptive statistics: Frequencies Result presentation: Tables, Figures

3.6.1 Data Validity and Reliability Tests

This section describes the procedures employed to measure the reliability and validity of the variable measured. These methods of analysis are covered in the sections that follow.

3.6.2 Skewness and Kurtosis

The skewness and kurtosis were calculated using SPSS IBM 27. Skewness is zero in a normal distribution, while skewness should be near zero with symmetric data. Negative skewness values indicate data tilted to the left, whereas positive skewness values indicate data tilted to the right. Skewed left means that the left tail is longer than the right tail. Similarly, a skewed right demonstrates that the right tail is longer than the left tail. If the data is multi-modal, the sign of the skewness may change (Khoussi *et al*., 2021).

The guideline to remember is that if any of these skewness or kurtosis values are less than 1.0 and the distribution's skewness or kurtosis is not beyond the normal range, then the distribution may be considered normal. But if the values are greater than ±1.0, the distribution's skewness or kurtosis is beyond the normal limits; thus, the distribution cannot be called normal. (Saarinen, 2022). If the skewness value is greater than + 1.0, the distribution is right-skewed. If the distribution is less than -1.0, the distribution is skewed to the left. The distribution is leptokurtic if the value of kurtosis is greater than + 1.0. If the value is less than 1.0, the distribution is platykurtic.

3.6.3 Mean Item Score (M.I.S)

The M.I.S is obtained by finding the average of the five-point scores of the study participants divided by the number of assessed variables that comprise the Likert scale (Wu and Leung, 2017). In this study, the mean item score was employed as one of the measurement models' validity and reliability tests (used to test the significance of the measured variables). This study computed the M.I.S for the assessed variables using SPSS (version 27).

$$\text{Mean item score} = \frac{{}^{1}n_1 + {}^{2}n_2 + {}^{3}n_3 + {}^{4}n_4 + {}^{5}n_5}{N} \qquad \text{Equation 3.2}$$

Where, N = total respondents,
n_1 *= number of partakers suggesting 1 on the Likert scale,*
n_2 *= number of partakers suggesting 2 on the Likert scale,*
n_3 *= number of partakers suggesting 3 on the Likert scale,*
n_4 *= number of partakers suggesting 4 on the Likert scale,*
n_5 *= number of partakers suggesting 5 on the Likert scale.*

3.6 4 Relative Important Index (R.I.I)

Relative Important Index (R.I.I.) is defined by Eadie (2013) as a method used in analysing categorical data, which involves using a five-point Likert scale. It was also used in this research for the same purpose. Table 3.5 show the rating scale employed

Table 3.5 Relative Important Index rating

RII values	Usage level
0.81 to 1.0	Very high
0.61 to 0.8	High
0.41 to 0.6	Average
0.21 to 0.4	Low
0.00 to 0.20	Never

3.6.5 Factor Analysis

Confirmatory factor analysis (CFA) is a confirmatory test of the validity of measurement models. It demonstrated the measured variables' convergent and discriminant validity and reliability and confirmed the set of measured variables' intended internal structure (Marsh *et al*., 2014; Harrington, 2009; Bandalos and Finney, 2018). In this study, confirmatory factor analysis was used to examine if the measured variables are compatible with the nature of the connected component. Principal Components Analysis was used as the extraction method. Tables 4.11 and 4.12 show the minimum criteria used to conduct the analysis: "factor loading, eigenvalue, correlation coefficient, Kaiser-Meyer-Olkin (KMO) value, Bartlett's test results, and average variance explained (AVE)". In this study, the CFA findings were utilised to confirm the validity and reliability of the measured variables. SPSS IBM (version 27) was used to conduct the analysis.

The product-moment correlation coefficients between the constructs and the measured variables are referred to as factor loading (Bandalos and Finney, 2018). It denotes the relationship between the constructs and measured variables (Marsh *et al*., 2020). "Eigenvalues represent the variances of the measured variables" (Fan, Guo and Zheng, 2022). This implies that it measures the amount of variance explained by the constructs in the measured variables. The correlation coefficient indicates the connection strength between the variables under consideration (Marsh *et al*., 2020). The KMO value is a sample adequacy measurement that reveals how much of the variance in measured variables is generated by a construct (Shrestha, 2021). The outcomes of Bartlett's test aid in determining if the measured variables have a suitable inner structure (that is, if the measured variables are related). The quantity of variation in measured variables explained by a construct is shown by AVE, which assesses convergent validity (Bandalos and Finney, 2018, Shrestha, 2021). Also, a scree plot was used to show the grouping of the variables. A scree plot is a straight-forward line segment plot that displays the eigenvalues of each individual component group (Papandrea *et al*., 2020). The eigenvalues are shown on the y-axis, while the number of factors is shown on the x-axis. It always has a downward slope (Liu *et al*., 2022). This was also used in this study to display the structural flow of the clustered components.

Tables 3.6, 3.7 and 3.8 are used to show the criteria used to conduct the factor analysis for the BIM barriers and BIM impacts.

Table 3.6 Guide for factor loading selection based on response rate.

S/N	Value of Factor Loading	Response rate
1.	.75	50 -59
2.	.70	60 – 69
3.	.65	70 – 99
4.	.55	100 – 119
5.	.50	120 – 149
6.	.45	150 – 199
7.	.40	200 – 249
8.	.35	250 – 349
9.	.30	350 and above

Table 3.7 Guide to conducting PCA for the identified barriers

S/N	Criteria	Parameter		
		Minimum Required	South Africa	Nigeria
1.	Factor loading value	.30	≥.55	≥.40
2.	Eigen factor value	>1		
3.	Kaiser-Meyer-Olkin (KMO) test	0.5	.777	.814
4.	Bartlett's Test of Sphericity		1428.953	1881.715
5.	p-value		0.000	0.000
6.	Variable to the respondent ratio	1:1.5	1:3.06	1:8.24
7.	Percentage of Variance	50%	62.444	53.432
8.	Variable Communality Value ≥.05	05		.411 to .673
9.	Reliability Statistics (Cronbach α)	.60	.921	0.853

Table 3.8 Criteria for conducting PCA for BIM impact.

S/N	Criteria	Parameter		
		Minimum Required	South Africa (SA) N=101	Nigeria (NG) N=272
1.	Reliability Statistics (Cronbach α)	0.65	0.961	0.815
2.	Factor loading value significance level	SA .55 NG .35	≥.70	≥.40
3.	Eigenvalues	>1		
4.	Kaiser-Meyer-Olkin (KMO) test	0.5	.940	.854
	Bartlett's Test of Sphericity	0.5	1220.662	799.697
	Df and Sig.			136 _ .000
5.	Variable to the respondent ratio	1:1.5	1:5.94	1:16
6.	Percentage of Variance	50%	63.455	52.059
7.	Variable Communality Value ≥.05	05	.604 to .766	.511 to .673
8.	Parallel Analysis test	Real eigenvalue factor > random order eigenvalue factor		

3.6.6 Cronbach's Alpha Coefficient

Cronbach's α coefficient is used to calculate the reliability of measured variables (Ravinder and Saraswathi, 2020). A quantitative analysis method uses Cronbach's α coefficient to evaluate the internal reliability of the measured variables on the Likert scale (Amirrudin *et al.*, 2021). Kaewnaknaew *et al.* (2022) affirmed that internal consistency determines how consistent the study participants' responses to the measured variables are. Cronbach's values for the variables investigated in this study were calculated using SPSS IBM (version 27). The mathematical expression of Cronbach's α coefficient is presented in Equation 3.3 which measures the variables as explained.

Cronbach Alpha (α) Coefficient = [k/(k-1)] * [1-(Σσi2/σx2)] *Equation 3.3*

k is the number of items/factors

Σσi2is the sum of item variances

σx2is the total variance of the scale

3.6.7 Kruskal-Wallis Test

The Kruskal-Wallis test is a nonparametric test that compares two or more unmatched groups. The Kruskal-Wallis test by ranks, (H test) or one-way ANOVA on ranks is a non-parametric method for determining if samples come from the same distribution (Hecke, 2012). It is used to compare two or more independent samples of the same or different sizes (Hecke, 2012; Johnson, 2022). This study uses the Kruskal-Wallis test to check if the distribution of the variables in a particular item group is the same across the dependent variable categories.

3.6.8 Pairwise Comparisons

This type of analysis is used to check the level of disagreement between the perspectives of different dependent variables over an independent variable (Heckel *et al*., 2019). In this study, it was used along with the Kruskal-Wallis test to further determine where there is perspective disagreement among the dependent variables.

3.7 RESEARCH ETHICS

According to Tiidenberg (2020), research ethics are the guidelines and procedures for conducting credible research. It is crucial for ensuring research validity, credibility, and authenticity (Davies, 2020). According to Tiidenberg (2020), as a researcher, you have access to several procedural ethical rules in every study area. According to the author, these rules focus on doing no harm and are enforced by research organisations' ethics supervision procedures, such as review boards. Nonetheless, informed consent and confidentiality requirements appear to be the most effective ways of preventing harm. This emphasis on damage prevention might be viewed as the fundamentals of research ethics (Tiidenberg, 2020; Davies, 2020). Based on DUT ethical categories, this study falls within category II. This is low-level risk research since it only gathers data from professionals in the construction industry who acknowledged their engagement in an online survey, (see Appendix 14 to 16) for the approval. The data was gathered anonymously and with regard to confidentiality and individual rights. The study tools were intended to ensure the anonymity of research participants by not collecting private information. As noted in the informed consent application, the research instruments for this investigation were submitted for clearance to the Durban University of Technology Research Ethics Committees (see Appendix 13). The Ethics Committee provided clearance for the study instruments after scrutinising them and confirming their compliance with DUT's ethical principles and research standards. The information gathered from the respondents was presented truthfully, accurately, and impartially.

3.8 RESEARCH PHILOSOPHY AND METHODOLOGY SUMMARY

This section presented the philosophical foundation (orientation and viewpoint) that drives the study's research design. The chapter defined the study's ontological perspective, methodological approach, research strategy and epistemological position. This study's epistemological viewpoint stressed the importance of empirical data in understanding the extent to which BIM technology is used by the construction and maintenance managers in Nigeria's and South Africa's construction industries. The research strategy was positivism, based on the orientation of the research and the philosophical position of the study. Therefore, a quantitative-driven research design was chosen. The chapter also discussed the research's study and target populations, the sampling procedure, selection strategy, questionnaire design process, selection criteria, data gathering techniques and data analysis methods.

CHAPTER FOUR: DATA ANALYSIS, RESULTS PRESENTATION AND DISCUSSION: SOUTH AFRICAN

4.1 INTRODUCTION

The data received from the field are analysed and presented in two chapters (Chapters Four and Five). This chapter specifically presents the analysis of data, interpretation of analysis and discussion of the survey results from South Africa. The methods of analysis listed in Table 3.4 in the previous chapter are used in the analysis of the research data in this chapter. For clarity, the results are presented in Tables, Figures and Charts.

4.2 DEMOGRAPHIC INFORMATION OF RESPONDENTS

This research survey generated 105 completed inputs from SACPCMP professionals. The initial screening eliminated four respondent inputs since the respondents indicated they were unaware of BIM technology. Thus, 101 valid responses passed the initial screening. Figure 4.1 illustrates the gender distribution of the South African respondents: 84 (83.17%) were male and 17 (16.83%) were female. Based on academic qualification, Figure 4.2 shows the distribution of the respondent's highest level of education at the time of the survey, Master's degree 46, Honours 27, B. Tech/B. Sc 17, PhD 10 and National Diploma 1. This result indicates that the respondents are academically knowledgeable. Thus, they can provide relevant information with regard to the study.

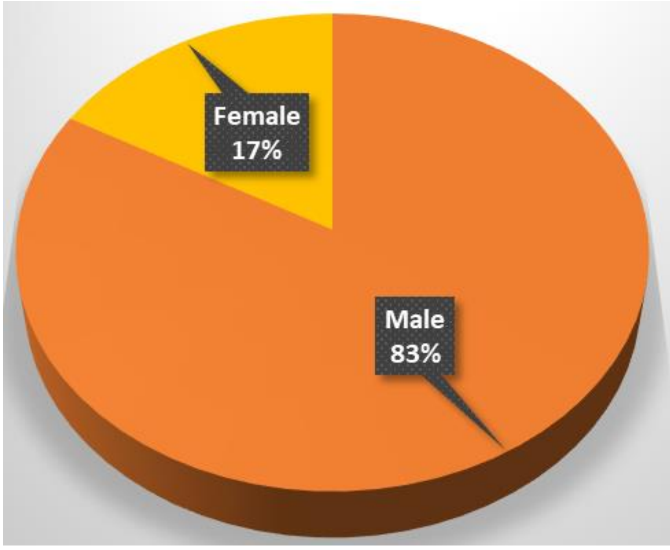


Figure 4.1 Respondent gender distribution

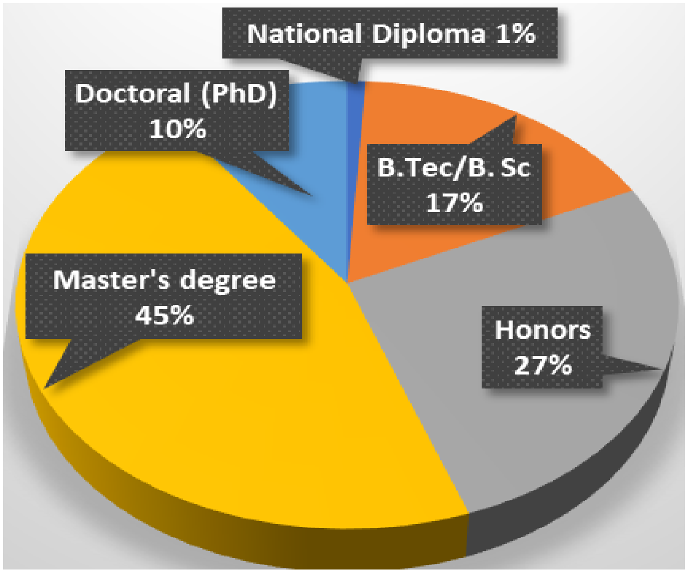


Figure 4.2 Educational level

The distribution of the respondent's professional backgrounds, as shown in Figure 4.3; comprises construction managers, builders, engineers, quantity surveyors and architects. These are the major professionals in the South African built environment who are saddled with the responsibility of managing building production. Furthermore, Figure 4.4 shows the respondents' years of experience: 39 respondents have over 20 years of work experience, 36 have 16-20 years, 20 have 11-15 years, and 6 have 5-10 years of work experience. This implies that the respondents are well-experienced in their professional pursuits and can provide adequate information relating to the survey questions

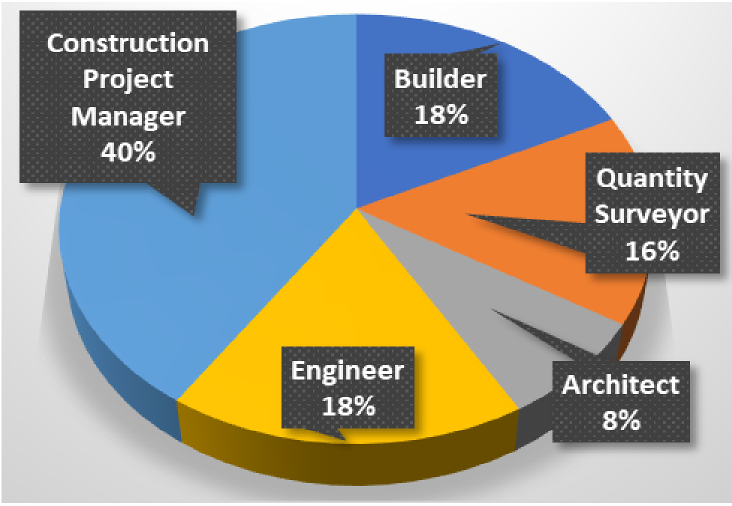


Figure 4.3 Categories of professionals

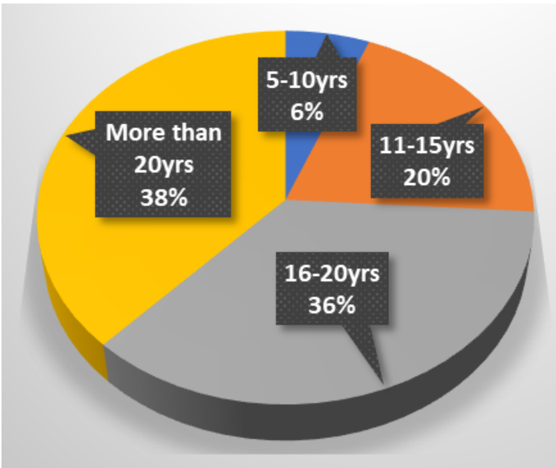


Figure 4.4 Years of experience

4.3 LEVEL OF INVOLVEMENT IN BUILDING PRODUCTION

From the results presented in Table 4.1, builders and construction project managers had the highest ratings in the construction stage, with MIS 4.17 and 4.28, respectively. This was affirmed in Oral's (2010) study, where the author compares the construction management practices in the United States and Turkey. It was noted that those professionals are primarily championing the management of the construction project. At the design stage, the results show the architect and construction project manager had the highest ratings, with 4.22 and 4.14 mean MIS, respectively. A recent study conducted by Toyin and Mewomo (2022b) in Nigeria concluded that the input of construction managers in the design stage is becoming more critical than before due to the innovations revolving around the construction industry. Also, during the post-construction stage, the engineer possesses the highest level of involvement among other professionals, with MIS 3.12.

Moreover, Atkin and Brooks' (2021) study also indicated that engineers are more involved in the post-construction stage of building facilities than other professionals. However, the Architect indicated the least involvement with MIS 2.32. Generally, it could be concluded that all the professionals involved in the survey participated substantially in the design and construction stages. They had a general average MIS of 4.01 and 4.00, respectively. However, their primary duties could be traced to their slightly low involvement in the post-construction stage.

Table 4.1 Level of involvement in building production stages

Profession	Design stage		Construction stage		Post-construction stage	
	Mean	SD	Mean	SD	Mean	SD
Builder (N=18)	3.87	.943	**4.17**	.707	2.98	.895
Quantity Surveyor (N=15)	3.91	.775	3.97	.561	2.87	.516
Architect (N=8)	**4.22**	1.246	3.50	.926	***2.32***	.916
Engineer (N=15)	3.96	1.208	4.12	1.298	**3.12**	.986
Construction Project Manager (N=36)	**4.14**	.931	**4.28**	1.059	2.96	1.054

4.5 BIM AWARENESS AND USAGE LEVEL AMONG PROFESSIONALS

From this study's general survey result, it was found that four respondents out of the initial 105 indicated that they were not aware of BIM technology, leaving 101 respondents who attested that they are aware of BIM technology. Nevertheless, Figure 4.5 shows the level at which the respondent used BIM across the construction phases. This implies that 9% of the respondents had not engaged in a project that warrants them to apply BIM or was not privileged to use BIM in a building project, despite being fully aware of BIM use in managing construction projects. In the study of Olapade and Ekemode (2018), the authors weigh the level of awareness of BIM use for facility management (FM); the result shows that the number of professionals aware of BIM use for FM is not proportionate to those using BIM. This denotes that more professionals are aware of BIM but have not had the opportunity to use it for any projects. This could be a result of its newness in the Nigerian construction industry.

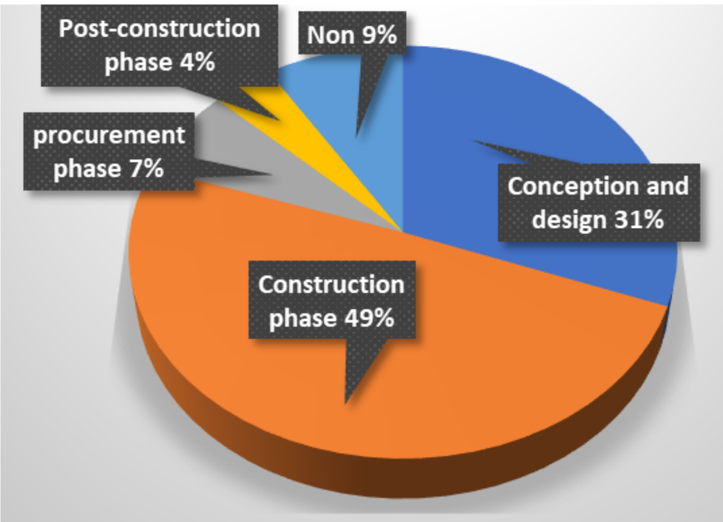


Figure 4.5 Phases of BIM tool used in construction

4.5.1 Level of BIM awareness

The respondents' level of BIM awareness was assessed using the seven identified variables gleaned from the literature. The results in Table 4.2 indicates that "BIM Awareness South Africa" (BAS) BAS1, BAS2, and BAS5 are abnormally distributed, the skewness is left-skewed, and the kurtosis is leptokurtic. Whereas BAS7, BAS6, BAS4 and BAS3 are normally distributed, refer to Appendix 1 for the variable's coding meaning. Based on the histogram interpretation, the following should be understood: 3 is the centre; towards 1, it is referred to as right, while towards 5, it is referred to as left. BAS1: "The term BIM-T is more discussed or talked about these days" was ranked first among the variables with a 4.25 mean. This means there has been an increase in BIM awareness in the country from a few years ago to the present. The study by Froise and Shakantu (2014) in South Africa recorded a 79% awareness rate among professionals. This survey shows an improvement, with 96.19% of the respondents attesting to being aware of BIM. Therefore, it could be assumed that the present registered built environment professionals are fully aware of BIM in South Africa. While BAS3: "Government adopt BIM-T use for public sector building construction in South Africa", was ranked with a mean above average: 3.24. Nevertheless, the government can still do better by enforcing the technology fully in the country, as it has been done in developed countries. Mtya and Windapo (2019) had previously suggested that BIM technology should be implemented in the South African construction industry.

Table 4.2 Level of BIM Awareness in South Africa

Descriptive Statistics						
Coding	Mean	Std. Dev.	Variance	Skewness	Kurtosis	Distribution
BAS1	4.25	.876	.768	-1.236	1.500	Abnormal Distribution
BAS7	4.15	.932	.868	-.984	.854	Normal distribution
BAS2	4.12	.852	.726	-1.024	1.773	Abnormal Distribution
BAS5	4.06	.998	.996	-1.167	1.452	Abnormal Distribution
BAS6	3.97	.974	.949	-.734	.192	Normal distribution
BAS4	3.70	.819	.671	-.400	.354	Normal distribution
BAS3	3.24	1.078	1.163	-.588	-.211	Normal distribution

Figures 4.6 and 4.7 show the normal and abnormal distribution samples extracted from the survey questionnaire data. These display the histogram chart of how respondents rate their opinion on the 5-point Likert scale.

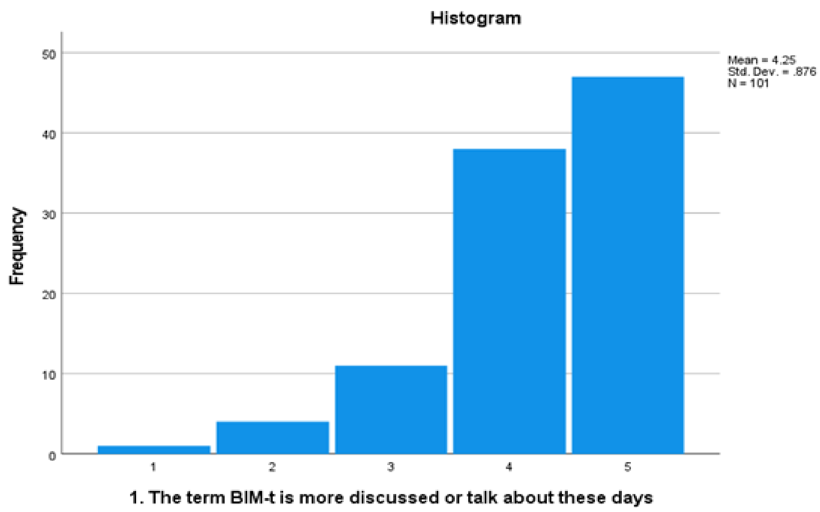


Figure 4.6 BA1 respondent rating left-skewed

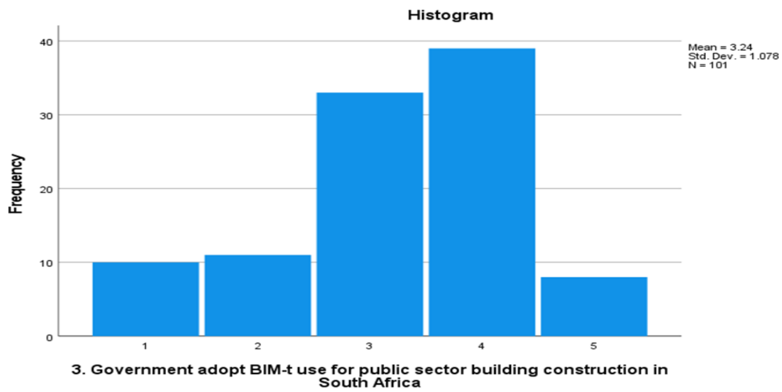


Figure 4.7 BA3 respondent rating normal distribution

4.5.2 Usage of BIM tools

Understanding the BIM process and using BIM tools are significant to its adoption in the construction industry at different stages. Table 4.3 shows the identified tools frequently used in the construction industry during the lifecycle of building production although, each profession has particular BIM tools that are critical in discharging their duties (Wu *et al*., 2017). Table 4.3 shows the results of the data generated from the survey conducted within the SACPCMP in South Africa. The table presents the descriptive statistics: MIS, RII rating and ranking. From the survey result, it can be seen that 7 out of the 33 BIM tools have gained high usage among South African built environment professionals. At the same time, the rest are still within the average usage level.

Moreover, Chimhundu (2016) initially reported low use of BIM tools in South Africa. But with this recent survey, the story is drastically changing, as more professionals are now familiarising themselves with BIM tools. The survey results revealed an increase in the use of BIM technology among professionals, with only 8.91% of the 101 respondents having yet to utilise BIM. Thus, 8.91% were removed from the analysis; N=92.

Table 4.3 Level of BIM-T tools usage in South Africa

S/N	BIM-T tools level	Mean	Std. Dev.	RII	Level	Ranking
1.	Vectorworks Architect	3.04	1.257	.61	H	7th
2.	ArchiCAD	3.23	1.187	.65	H	6th
3.	Autodesk BIM 360	3.23	1.070	.65	H	5th
4.	SketchUp	3.33	1.049	.67	H	4th
5.	Revit	3.43	1.062	.69	H	3rd
6.	Navisworks	2.88	1.175	.58	A	10th
7.	Revizto	2.87	1.141	.57	A	11th
8.	Iris VR	2.92	1.294	.58	A	9th
9.	BEXEL manager	2.76	1.270	.55	A	15th
10.	Edificius	2.79	1.254	.56	A	13th
11.	ArCADia BIM 11	2.76	1.199	.55	A	14th
12.	VisualARQ	2.70	1.238	.54	A	17th
13.	Midas Gen	2.58	1.141	.52	A	22nd
14.	Civil 3D	3.01	1.134	.60	A	8th
15.	Buildertrend	2.78	1.127	.56	A	12th
16.	Hevacomp	2.62	1.156	.52	A	19th
17.	Sefaria	2.75	1.246	.55	A	15th
18.	BIMx	2.63	1.220	.53	A	17th
19.	AutoCAD	3.86	1.023	.77	H	2nd
20.	Bently Architecture	2.60	1.168	.52	A	18th
21.	Computerised Maintenance Management System (CMMS)	2.27	1.070	.45	A	30th
22.	Computer-Aided Facility Management (CAFM)	2.23	1.159	.45	A	32nd
23.	Integrated Workplace Management (IWMS)	2.05	.999	.41	A	33rd
24.	Building Automation System (BAS)	2.25	1.075	.45	A	31st
25.	Synchro Professional	2.33	1.039	.47	A	29th
26.	Vico Control	2.39	1.148	.48	A	27th
27.	Visual Application	2.35	1.104	.47	A	28th
28.	D Profiler	2.52	1.104	.50	A	23rd
29.	Vico Takeoff Manager	2.45	1.171	.49	A	26th
30.	QTO	2.48	1.181	.50	A	24th
31.	Navisworks Manager	2.58	1.092	.52	A	21st
32.	Microsoft Project	4.01	1.143	.80	H	1st
33.	Navisworks simulate	2.45	1.123	.49	A	25th

4.6 USES OF BIM-T FOR MAINTENANCE: PROFESSIONALS' PERSPECTIVE

4.6.1 Descriptive Analysis (BIM Use)

In this section of the survey, the professionals rated their level of agreement with the six main uses of adopting BIM that have gained significant recognition in the existing literature for post-construction activities (operation and maintenance of the facilities). Appendix 2 contains the interpretation of the variable coding.

Table 4.4 BUSA6 indicates "BIM helps to locate building elements and components, allowing for better inspection and management" ranked first among the variables having an overall M.I.S 4.18 and R.I.I 0.84. This finding is in agreement with Habte and Guyo (2021); Tezel *et al*. (2021); Zaini *et al*. (2020). The authors also identified this factor as a significant contribution of BIM in facility management.

The remaining five variables, BUSA1, BUSA4, BUSA5, BUSA2 and BUSA3, were ranked 2nd - 6th, respectively. With overall M.I.S ranging from 3.79 - 3.98 with RII ranging from 0.75 to 0.80. These ratings fall within the threshold of the certified agreement by all the professionals with the listed BIM use. This implies that this identified variable is achievable with the use of BIM. Therefore, this study agrees with other studies from which those variables were identified.

Architects had the highest level of agreement with all variables, with MIS ranging from 4.13 to 4.75, while engineers had the lowest overall rating, with MIS ranging from 3.27 to 4.08. The slightly lower agreement from the engineers might be because of their different arms. Martin and Root (2010) noted the different engineering divisions from which they are saddled with various tasks, such as the structural engineers, electrical and mechanical engineers; as such, they may tend to have a different opinion on the management of building facilities.

Table 4.4 BIM used for maintenance descriptives analysis

Variables coding/ Professionals		N	Mean	Std. Dev.	RII	Ranking
BUSA1	Builder	18	4.06	1.110		
	Quantity Surveyor	15	3.93	.704		
	Architect	8	4.75	.463		
	Engineer	15	3.87	1.060		
	Construction Project Manager	36	3.83	1.000		
	Total	92	3.98	.972	0.80	2nd
BUSA2	Builder	18	4.06	1.056		
	Quantity Surveyor	15	4.33	.724		
	Architect	8	4.38	.744		
	Engineer	15	3.27	.704		
	Construction Project Manager	36	3.86	1.125		
	Total	92	3.92	1.008	0.79	5th
BUSA3	Builder	18	4.00	1.138		

Variables coding/ Professionals		N	Mean	Std. Dev.	RII	Ranking
	Quantity Surveyor	15	4.07	1.033		
	Architect	8	4.13	.641		
	Engineer	15	3.60	.910		
	Construction Project Manager	36	3.58	1.204		
	Total	92	3.79	1.085	0.75	6th
BUSA4	Builder	18	4.33	1.029		
	Quantity Surveyor	15	4.00	1.000		
	Architect	8	4.25	.463		
	Engineer	15	3.67	.816		
	Construction Project Manager	36	3.78	1.174		
	Total	92	3.95	1.031	0.79	3rd
BUSA5	Builder	18	4.11	.963		
	Quantity Surveyor	15	4.07	1.223		
	Architect	8	4.38	.744		
	Engineer	15	3.67	1.047		
	Construction Project Manager	36	3.83	1.207		
	Total	92	3.95	1.103	0.79	4th
BUSA6	Builder	18	4.28	1.074		
	Quantity Surveyor	15	4.13	.640		
	Architect	8	4.75	.463		
	Engineer	15	4.13	.990		
	Construction Project Manager	36	4.06	.984		
	Total	92	4.18	.925	0.84	1st

4.6.2 Inferential Analysis (BIM Use)

It is proper to test the homogeneity hypothesis (Table 4.5) to check if a population with two or more samples has an equal variance. Thus, this study has more than two samples comprising the selected built environment professionals. Therefore, the null hypothesis “states that the populations' variances are equal, against the alternative hypothesis that at least one population variance is different”. When the p-value (sig.) test is less than 0.05, “reject the null hypothesis and conclude that the populations differ in variance”. Since the results of this analysis validate the equality of variance. Therefore, to accept the null hypothesis, a one-way ANOVA can be computed.

Table 4.5 Variances Homogeneity test

		Levene Statistic	df1	df2	Sig.
BUS A1	Based on Mean	1.322	4	87	.268
	Based on Median	1.292	4	87	.280
	Based on Median and with adjusted df	1.292	4	79.310	.280
	Based on trimmed mean	1.224	4	87	.306
BUS A2	Based on Mean	.825	4	87	.513
	Based on Median	.562	4	87	.691
	Based on Median and with adjusted df	.562	4	74.700	.691
	Based on trimmed mean	.565	4	87	.689
BUS A3	Based on Mean	1.490	4	87	.212
	Based on Median	1.160	4	87	.334
	Based on Median and with adjusted df	1.160	4	80.046	.335
	Based on trimmed mean	1.411	4	87	.237
BUS A4	Based on Mean	1.348	4	87	.259
	Based on Median	1.028	4	87	.397
	Based on Median and with adjusted df	1.028	4	72.693	.399
	Based on trimmed mean	1.164	4	87	.332
BUS A5	Based on Mean	1.271	4	87	.288
	Based on Median	.684	4	87	.605
	Based on Median and with adjusted df	.684	4	67.598	.605
	Based on trimmed mean	.914	4	87	.459
BUS A6	Based on Mean	1.918	4	87	.115
	Based on Median	1.695	4	87	.158
	Based on Median and with adjusted df	1.695	4	57.871	.164
	Based on trimmed mean	1.946	4	87	.110

A “one-way ANOVA” is used to assess whether the means of three or more independent groups differ statistically. If the significant value is less than 0.05, there is a significant difference. Therefore, there would be a need to conduct post-hoc comparisons using a “Multiple Comparisons” test using Tukey HSD (Toyin and Mewomo, 2022b). Table 4.6 shows no significant difference in the professional's perspective over the following variables: (BUSA1, BUSA3, BUSA4, BUSA5 and BUSA6). At the same time, there is a significant difference in BUSA2: “It is used to plan maintenance route (Predictive and Preventive)” with an F value of 2.769 and a Sig. value of .024. Because there is a significant difference in the professionals' points of view, it is necessary to determine the source of the difference. Thus, further analysis was conducted using post-hoc comparisons (Kim, 2017). The post-hoc comparisons result in Table 4.7 reveal a significant difference between the Quantity Surveyor and Engineer perspective view over BUSA2 with a p-value of .027. This result indicated that Quantity

Surveyors have less experience using BIM for facility management than Engineers. The complete result for Table 4.7 can be seen in Appendix 3.

Table 4.6 BIM uses one-way ANOVA results.

ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
BUSA1	Between Groups	5.845	4	1.461	1.587	.185
	Within Groups	80.111	87	.921		
	Total	85.957	91			
BUSA2	Between Groups	11.076	4	2.769	2.960	.024
	Within Groups	81.392	87	.936		
	Total	92.467	91			
BUSA3	Between Groups	4.918	4	1.229	1.047	.388
	Within Groups	102.158	87	1.174		
	Total	107.076	91			
BUSA4	Between Groups	5.673	4	1.418	1.355	.256
	Within Groups	91.056	87	1.047		
	Total	96.728	91			
BUSA5	Between Groups	3.809	4	.952	.775	.545
	Within Groups	106.919	87	1.229		
	Total	110.728	91			
BUSA6	Between Groups	3.392	4	.848	.991	.417
	Within Groups	74.467	87	.856		
	Total	77.859	91			

Table 4.7 BIM uses post-hoc comparisons result (Tukey HSD)

	(I) Professionals	(J) Professionals	Mean Difference (I-J)	Std. Error	Sig.
BU2	Builder	Quantity Surveyor	-.278	.338	.923
		Architect	-.319	.411	.937
		Engineer	.789	.338	.144
		Construction Project Manager	.194	.279	.957
	Quantity Surveyor	Builder	.278	.338	.923
		Architect	-.042	.423	1.000
		Engineer	1.067*	.353	.027
		Construction Project Manager	.472	.297	.509
	Architect	Builder	.319	.411	.937
		Quantity Surveyor	.042	.423	1.000
		Engineer	1.108	.423	.076
		Construction Project Manager	.514	.378	.655
	Engineer	Builder	-.789	.338	.144
		Quantity Surveyor	-1.067*	.353	.027
		Architect	-1.108	.423	.076
		Construction Project Manager	-.594	.297	.275
	Construction Project Manager	Builder	-.194	.279	.957
		Quantity Surveyor	-.472	.297	.509
		Architect	-.514	.378	.655
		Engineer	.594	.297	.275

Note: The (*) indicate where there is Sig. difference between the mean score of the professionals

4.7 BARRIERS HINDERING THE APPLICATION OF BIM

4.7.1 Descriptive Analysis (BIM Barriers)

This study identified 33 barriers to BIM application in developing countries' construction industries. There is a good chance that these barriers measure some shared properties of the inherent dimensions described as factors or hidden variables. Though the most critical obstacles were determined by ranking based on Mean, RII, and Standard Deviation, the rating levels are shown in Table 4.8

Table 4.8 Criticality level based on RII rating

RII values	Criticality level	codes
0.81 to 1	Very Critical	VC
0.61 to 0.8	Critical	C
0.41 to 0.6	Average	A
0.21 to 0.4	Less Critical	LC
0 to 0.2	Not Critical	NC

Table 4.9 demonstrates that just two barriers, BCSA2 and BCSA25, are considered highly crucial, while the remaining hurdles are deemed critical. Based on these findings, it is possible to conclude that all the obstacles are related to the South African construction industry. Therefore, there is a need to further look for means of explaining the variables in a simpler analytical method, such as factor analysis (Toyin and Mewomo, 2022b). The factor analysis goal was to detect and create comparable underlying effects that can readily describe the model of correlations within a collection of observable variables (Bandalos and Finney, 2018). The technique can assist in reducing the size of the data. Typically, a collection of connected barriers is reduced to a more manageable and concise size of barriers that explain most of the variance found in a much greater number of separate barriers (while retaining as much of the original information as possible).

Table 4.9 BIM barriers rating

Descriptive Statistics N=101					
Barrier codes	Mean	Std. Dev.	RII	Criticality Level	Ranking
BCSA2	4.05	.930	.81	VC	1st
BCSA25	4.03	.919	.81	VC	2nd
BCSA12	3.92	1.008	.78	C	3rd
BCSA23	3.85	.983	.77	C	4th
BCSA13	3.84	.868	.77	C	5th
BCSA26	3.84	1.051	.77	C	6th
BCSA14	3.83	.872	.77	C	7th
BCSA20	3.83	.933	.77	C	8th
BCSA16	3.83	.979	.77	C	9th
BCSA1	3.83	1.085	.77	C	10th
BCSA6	3.82	.983	.76	C	12th
BCSA32	3.82	.925	.76	C	11th
BCSA24	3.80	1.019	.76	C	13th
BCSA4	3.79	.896	.76	C	14th
BCSA17	3.78	1.004	.76	C	15th
BCSA33	3.78	1.036	.76	C	16th
BCSA19	3.76	1.093	.75	C	18th
BCSA5	3.76	.942	.75	C	17th
BCSA9	3.73	1.017	.75	C	19th
BCSA29	3.72	1.009	.74	C	20th
BCSA21	3.72	.964	.74	C	23rd
BCSA7	3.72	.987	.74	C	22nd
BCSA18	3.72	.964	.74	C	20th
BCSA3	3.71	1.011	.74	C	24th
BCSA15	3.70	.958	.74	C	25th
BCSA30	3.68	1.016	.74	C	26th
BCSA22	3.66	.964	.73	C	27th
BCSA27	3.64	.967	.73	C	28th
BCSA31	3.62	1.036	.72	C	29th
BCSA28	3.60	.973	.72	C	30th
BCSA11	3.60	1.017	.72	C	31st
BCSA10	3.49	1.022	.70	C	32nd
BCSA8	3.46	1.094	.69	C	33rd

4.7.2 Factor Analysis (BIM Barriers)

This study conducted factor analysis using the principal component analysis (PCA) extraction method on the 33 identified barriers using orthogonal rotation (varimax). However, the sample size is one of the several datasets that factor analysis depends on to check for data suitability and reliability. Different perspectives on the sample size required for factor analysis have emerged. According to de Winter *et al*. (2009), the sample size should be more than 50. In 2020, Isa *et al*. (2020) suggested a range of respondent rates (Table 3.6) for the sample size to conduct PCA; with their associated factor loading values, Toyin and Mewomo (2022b) adopted this in a survey with over 300 respondents. As seen in Table 3.6, this study adopted .55 for its factor loading since it has a valid response rate of 101. Table 3.7 shows the guideline criteria adopted to conduct PCA on the 33 variables.

4.7.2.1 PCA: data reliability and adequacy check.

It is necessary to conduct a statistical reliability test on the generated data before proceeding to further analysis. This is to ensure that reliable data is obtained. To confirm that the instrument used is reliable, the value of alpha α must be greater than 0.65 (Kumar, 2018). Thus, the alpha α value for the 33 variables surveyed was .921. Therefore, the result of this study indicates a strong internal consistency, and the questionnaire used possessed high reliability and internal consistency.

KMO and Bartlett's test of sphericity is commonly used in PCA to assess sample adequacy (Malhotra and Birks, 2006). When Bartlett's sphericity test is significant (P 0.05) and the KMO index is greater than 0.5, the dataset is typically suitable for factor analysis (Mane and Nagesha, 2014). In this investigation, the KMO test yielded a value of 0.777; however, Bartlett's test yielded a statistically significant result of (chi-square = 1428.953, p = 0.000). As a result, the results are compatible with the use of PCA.

4.7.2.2 Component correlation Matrix (CCM)

The CCM shows the statistical correlation among the extracted components or factors, and the result is used to choose between orthogonal and oblique rotation. Table 4.10 shows the CCM result for this study’s barrier-related variables. The reason for showing this table is to check which rotation is adequate for the PCA. From the CCM table, it is required to check for any correlation between factors or components greater than .32 or less than -.32. There are no components in this table that are greater than .32 or less than -.32. As a result, orthogonal rotation can be used. Note: orthogonal rotation generates uncorrelated factors, and oblique rotation generates factors that can be correlated with each other. From Figure 4.8, the left graph represents orthogonal rotation (i.e., maintaining a 90° angle between axes), and the right graph represents oblique rotation (i.e., allowing the X and Y axes to assume a different angle other than 90º). At the same time, the stars denote the loadings of the initial variables on the factors.

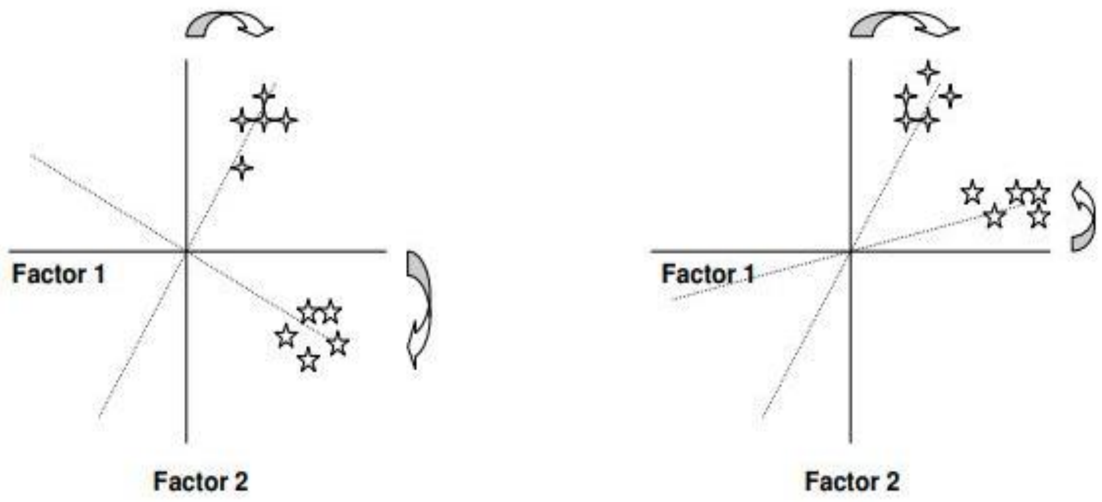


Figure 4.8 Graphical representation of factor rotation (Adapted from (Field, 2000))

Table 4.10 Component correlation matrix

Component	1	2	3	4	5	6	7	8
1	1.000	.218	.218	.279	.240	-.168	.129	.048
2	.218	1.000	.171	.257	.268	-.006	.028	.005
3	.218	.171	1.000	.212	.175	-.121	.104	.103
4	.279	.257	.212	1.000	.158	-.147	.172	.089
5	.240	.268	.175	.158	1.000	-.084	.086	.111
6	-.168	-.006	-.121	-.147	-.084	1.000	-.082	-.007
7	.129	.028	.104	.172	.086	-.082	1.000	.037
8	.048	.005	.103	.089	.111	-.007	.037	1.000

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalisation.

Figure 4.9 shows that eight components with eigenvalues greater than 1.0 were extracted with the variance explained by each component. Component 1 contributed 27.272%, Component 2 contributed 7.507%, Component 3 contributed 6.514%, Component 4 contributed 5.428%, Component 5 contributed 4.459%, Component 6 contributed 4.176%, Component 7 contributed 3.856%, and Component 8 contributed 3.243%. Altogether, the eight components explained summed up 62.455% of the variability in the original 33 barriers to the application of BIM in the South African construction industry. Shrestha (2021); Marsh *et al*. (2020) and Bandalos and Finney (2018) suggested that 50% and above is adequate for the variability of variance in order to conduct PCA analysis. Therefore, computing 62.455% means that this study can be further analysed using rotated component grouping.

Total Variance Explained

Component	Initial Eigenvalues Total	% of Variance	Cumulative %	Extraction Sums of Squared Loadings Total	% of Variance	Cumulative %	Rotation Sums of Squared Loadings Total	% of Variance	Cumulative %
1	9.000	27.273	27.273	9.000	27.273	27.273	4.138	12.539	12.539
2	2.477	7.507	34.780	2.477	7.507	34.780	3.175	9.620	22.160
3	2.149	6.514	41.293	2.149	6.514	41.293	3.133	9.494	31.654
4	1.791	5.428	46.722	1.791	5.428	46.722	2.935	8.893	40.547
5	1.471	4.459	51.180	1.471	4.459	51.180	2.469	7.481	48.028
6	1.378	4.176	55.357	1.378	4.176	55.357	1.766	5.353	53.380
7	1.272	3.856	59.212	1.272	3.856	59.212	1.741	5.276	58.656
8	1.070	3.243	62.455	1.070	3.243	62.455	1.254	3.799	62.455
9	.989	2.996	65.451						
10	.961	2.914	68.365						
11	.866	2.624	70.989						
12	.832	2.521	73.510						
13	.785	2.380	75.890						
14	.733	2.223	78.113						
15	.705	2.136	80.249						
16	.652	1.976	82.225						
17	.593	1.798	84.023						
18	.547	1.657	85.680						
19	.511	1.547	87.227						
20	.499	1.512	88.739						
21	.471	1.427	90.165						
22	.443	1.344	91.509						
23	.407	1.233	92.742						
24	.359	1.088	93.830						
25	.353	1.068	94.899						
26	.330	1.000	95.899						
27	.279	.845	96.744						
28	.248	.751	97.495						
29	.236	.716	98.212						
30	.185	.562	98.773						
31	.160	.486	99.259						
32	.126	.380	99.640						
33	.119	.360	100.000						

Extraction Method: Principal Component Analysis.

Figure 4.9 Total variance explained on BIM application barriers

4.7.2.3 Scree plot graph

Nunayon *et al.*'s (2020) study reveals that a scree plot is the main reasonable way to validate the results of PCA. The plot simply displays the computed eigenvalues using SPSS, generally from the first eigenvalue, namely, the most explained variance, to the least eigenvalue (Malhotra and Birks, 2006). Thus, checking the scree plot alongside the component matrix's result is vital. This will strengthen the determination of the factors to be retained (Pallant, 2005).

Looking at the scree plot shown in Figure 4.10, the slope of the curve levels out as the explained variance flattens as each eigenvalue slowly reduces. As indicated in Figure 4.8, the extracted loadings generated eight factors. This is also shown in the scree plot. Thus, the number of elements obtained was the same as the number of data points above the pink line. Thus, data points that fell directly or below the pink line were not counted. Because eigenvalue is a conventional approach for factor extraction, it was examined in this study for the same purpose. They are useful in developing criteria for keeping the essential elements to be addressed in factor analysis (K'Akumu *et al*., 2013). The criterion for evaluating important factors was an eigenvalue ≥ one. The scree plot in Figure 4.10 shows that the ultimate solution occurs at a location on the vertical axis where the eigenvalue equals one. This was determined after eight data points. It confirms that only eight components could be extracted.

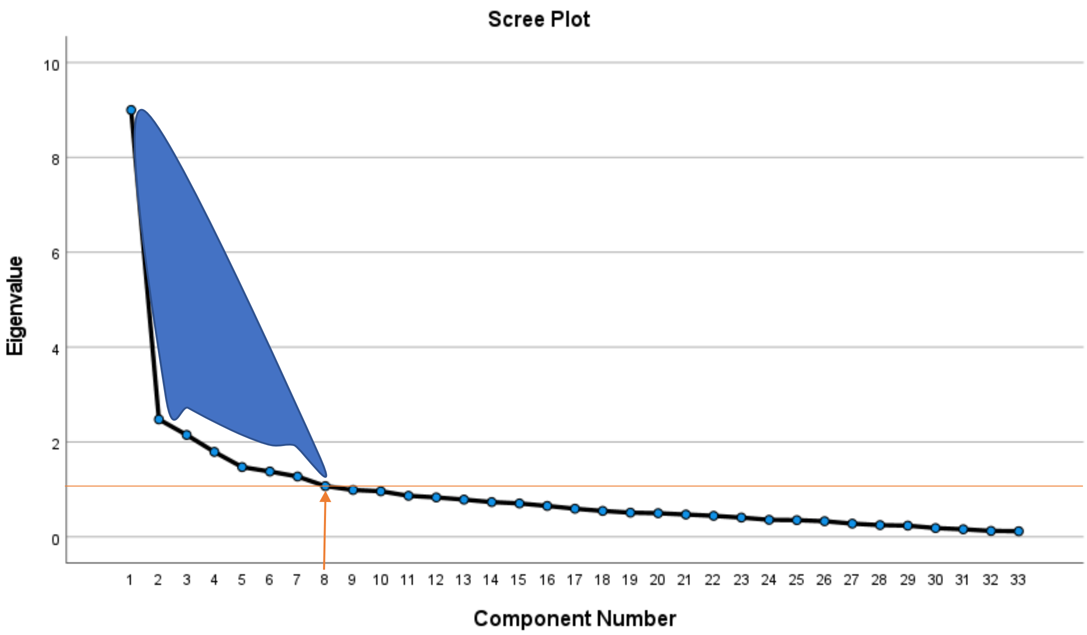


Figure 4.10 Total variance explained on BIM application barriers

Rotated component matrix

"The significance of a factor loading indicates the practical importance of a given variable to a given factor" (Nunayon *et al*., 2020). Generally, this significance depends on the valid sample size generated from the survey (Field, 2005; Isa, 2020; Toyin and Mewomo, 2022). For this study, the sample size was 101. Thus, the effective significant level to retain from the PCA rotated component matrix is ≥ 0.550. Appendix 5 shows the clustering of the variables into components and Table 4.11 shows the component naming.

Table 4.11 Rotated component factor interpretation of the 27 peculiar barriers

Component naming	Code	Factor Loading	Alpha
Component 1			.863
Legal related reason	BCSA29	.820	
	BCSA30	.751	
	BCSA28	.717	
	BCSA27	.683	
	BCSA31	.680	
	BCSA33	.589	
	BCSA32	.552	
Component 2			.783
Personnel related factor	BCSA4	.724	
	BCSA2	.708	
	BCSA5	.637	
	BCSA6	.588	
	BCSA3	.573	
	BCSA9	.553	
Component 3			.752
Environmental Influence	BCSA15	.737	
	BCSA16	.686	
	BCSA13	.671	
	BCSA17	.561	
Component 4			.743
Construction management circumstances	BCSA10	.776	
	BCSA21	.614	
	BCSA22	.570	
Component 5			.785
Economic and Financial Reasons	BCSA19	.755	
	BCSA23	.575	
			.860
	BCSA24	.683	
	BCSA25	.606	
Component 7			
Professional Workforce influences	BCSA1	.858	
Component 8			-.040
Management related factor	BCSA11	.702	
	BCSA12	-.559	

Component 1: Legal-related factor

Legal-related factors are barriers that involve the lawful guidance on how a process is to be followed and the definition of an innovation involving different parties. According to Barak *et al*. (2009), legally related barriers created by defective programming might end in a court case. There are numerous BIM software programmes, and multiple professionals commonly develop BIM models using software packages that they are familiar with and that are used by different users (Mirarchi *et al*., 2020). Assume a design-related document is missing in the process of sharing amongst relevant experts; owing to inappropriate usage or a lack of adequate knowledge of the BIM models, tracking and verification may become extremely difficult due to unclear ownership (Bouhmoud and Loudyi, 2021). The barriers found under this component are contractual BIM environment; unclear sole ownership right of BIM tool data; a lack of protocols in line with market demand; a missing insurance framework for BIM application; absence of insurance applicable to BIM application; an absence of support from policymakers, and a low knowledge about the BIM application ideologies and guidelines for certain project professionals" with the following parameters: factor loading: 0.820, 0.751, 0.717, 0.683, 0.680, 0.589, 0.552; ranking: 20th, 26th, 30th, 28th, 29th, 16th, 12th.

Component 2: Personnel-related factor

Personnel factors are the hurdles attributable to the professionals' behavioral attitudes regarding revolutionary technologies such as BIM. These impediments include an inadequate understanding of the benefits of BIM; an inadequate knowledge of BIM capabilities; a lack of commitment from senior officials in charge of construction activities to embrace BIM technology; resistance to change from the traditional design and construction approach; and a lack of support from owners and managers owing to a lack of understanding of BIM principles. Toyin and Mewomo (2022a) noted that for any innovative technology to gain ground, the personnel proposed to adopt it must be fully ready to learn and willing to adopt such technology. In practice, BIM-T destroys conventional constraints among diverse industry stakeholders and allows project information to be shared in a single system in certain collaborative situations. This implies that all stakeholders must understand their key functions within the project and restructure the firm's process to fit the BIM application's demands. This will affect the workflow, from design to file organisation to client billing and ultimate output. As a result, the built environment industry will require appropriate time to respond to these changes. (Sun *et al.,* 2017; Toyin and Mewomo, 2022).

Component 3: Environmental Influence

Environmental influence cannot be neglected regarding the adoption and application of BIM in the construction industry. Researchers (Tran-Hoang-Minh *et al*., 2021; Shin and Kim, 2021; Ahmed, 2018) have discovered that there are still some barriers related to environmental structures, and these limit the application of BIM. In this study, the following were grouped under this component: "difficulties on required training time; inadequate BIM data; inaccessibility to genuine BIM tools; complex process of learning BIM technology". These barriers have the following parameters extracted from the survey analysis: factor loading: 0.737, 0.686, 0.671 and 0.561; ranking 25^{th}, 9^{th}, 5^{th}, and $15^{th,}$ respectively.

Environmental influence refers to the limiting factors formed inside the building site's geographical location (Mewomo *et al*., 2021). BIM adoption necessitates professional, dynamic engagement throughout the project's life cycle. But the hindrance to genuine BIM tools and the scarcity of BIM data are predominant environmental barriers that could discourage the application of BIM (Wu *et al*., 2021). Therefore, there should be means of overcoming this hindrance to enable the smooth adoption of BIM.

Component 4: Construction management circumstances (CMC)

CMC refer to the administration and coordination attitude toward a wider application of BIM. These pose a great challenge in the BIM market. CMC barriers include: "negative attitude towards working collaboratively; Lack of organised BIM studying means; BIM consulting market is confused". These barriers have parameters as extracted respectively: factor loadings: 0.776, 0.614 and 0.570; ranking 32nd, 21st and 27th. Sun *et al.* (2017), in line with Toyin and Mewomo (2022), It is often assumed that construction experts prefer to use BIM technology, mostly owing to the fragmented nature of construction procedures, which makes each project unique and difficult to replicate.

Components 5 and 6: Economic and Financial Reasons

Economic and financial factors cited in this report include a lack of BIM specialists, high expenses associated with BIM software, hardware, and training, higher project planning costs, the cost of BIM experts, and the time necessary for training, with the following parameters: factor loadings of 0.755, 0.575, 0.683 and 0.606 and rankings of 17th, 4th, 13th and 2nd, respectively. This component's variables are deemed important, have a high factor loading, and are highly ranked among the variables. Thus, the instability and unstructured nature of the construction industry's ability to adopt innovative technology could lead to these barriers (Mtya and Windapo, 2019; Toyin and Mewomo, 2021). On the other hand, costs incurred in training professionals and implementing BIM technology in a construction project are among the threats that hinder the adoption of new technology in the construction industry. Hong *et al*. (2020) opined that the cost of renewing a software package could indicate a lot about its level of acceptance. This means that the cost of BIM tools will determine the categories of construction firms that can afford them. Therefore, it is expected that the cost will be reasonable to accommodate both small, medium and large construction firms.

Component 7: Professional Workforce influences (PWI)

PWI is the limiting factor related to professional computer literacy. Low computer skills, for example, have a factor loading of 0.858 among some construction professionals. This is a key limiting factor that leads to a scarcity of competent employees who are well-versed in the process of BIM technology implementation and who have gained sufficient abilities in managing BIM tools, ranking 10th among the studied obstacles. As a result, an adequate understanding of BIM education and the instruction of professional stakeholders is required (Saka and Chan, 2020). These will improve the complete and flawless application of BIM technology. According to Zhang (2010), most design firms (architectural, structural, M&E) find it challenging to utilise BIM due to limited product knowledge, the conventional fight against change, and the heavy labour demands experienced during the first stage of setting up BIM tools. This presents a significant hurdle to the successful use of BIM.

Component 8: Management-related factor

The management-related factor is the obstacle that arises because of the negligence of the experts in charge of BIM application portraits during the project lifecycle (Toyin and Mewomo, 2022a; Saka and Chan, 2020). This leads to the danger of losing crucial information during documentation throughout the project's lifespan, such as due to the lack of a stable BIM tool working environment and a lack of motivation to implement BIM in projects, and the top manager’s non-division of extra means of encouraging the professionals to learn the implementation of innovative technology. For employees to be happy in their assigned tasks, they must get extra allowances or motivation while doing the job. This is also applicable to the construction sector. Top managers are expected to encourage employees by sponsoring them to seminars and conferences to enhance their knowledge of the new technology.

4.8 BIM BENEFITS DURING CONSTRUCTION AND POST-CONSTRUCTION

4.8.1 BIM Benefit Kruskal-Wallis Test

The result of the respondents on the thirteen identified benefits was subjected to the Kruskal-Wallis test analysis. This test was conducted using SPSS for IBM 27. It was used to test the null hypothesis "if the distribution of the identified variables (BB1-BB13) is the same across the categories of professions". It should be noted that the p-value (sig.) **< 0.05** is usually considered statistically significant (Toyin and Mewomo, 2022b). Therefore, in such a case, the null hypothesis should be rejected. Thus, a p-value > 0.05 means that "deviation from the null hypothesis is not statistically significant, and the null hypothesis is retained". As seen in Table 4.12, the BB3 p-value is **0.019**. This result violated the null hypothesis statement, thus rejecting the null hypothesis. The rest of the variables accept the null hypothesis test, meaning there is no significant difference in the professionals' perspectives on the various BIM benefits. Table 4.11 shows the interpretation of the variable code.

Table 4.12 BIM Benefits

Variables code	Mean	Std. Div.	Sig.[a,b]	Ranking	Decision
BB1	4.27	.866	.340	3rd	Retain the null hypothesis.
BB2	4.36	.806	.484	1st	Retain the null hypothesis.
BB3	4.09	.934	.019*	11th	**Reject the null hypothesis.**
BB4	4.20	.940	.231	5th	Retain the null hypothesis.
BB5	4.13	.892	.614	10th	Retain the null hypothesis.
BB6	4.17	.968	.954	8th	Retain the null hypothesis.
BB7	4.23	.866	.556	4th	Retain the null hypothesis.
BB8	4.28	.830	.182	2nd	Retain the null hypothesis.
BB9	4.16	.893	.840	9th	Retain the null hypothesis.
BB10	4.18	.983	.964	7th	Retain the null hypothesis.
BB11	4.08	.929	.226	12th	Retain the null hypothesis.
BB12	3.97	1.084	.811	13th	Retain the null hypothesis.
BB13	4.18	.925	.200	6th	Retain the null hypothesis.

While conducting the Kruskal-Wallis test, it is essential to display the bar chart showing the perspective opinion of each rejected hypothesis. A similar management-related study (Toyin and Mewomo, 2022b) adopted this principle. Thus, SPSS will automatically generate it. The graph in Figure 4.11 shows that the Builder's rating is more focused (black bar) at the tip of 5, while the Architect's rating is between 4 and 3; this also shows the variations for other professionals. It implies that there is a significant difference between the perspectives of Quantity Surveyors and other professionals.

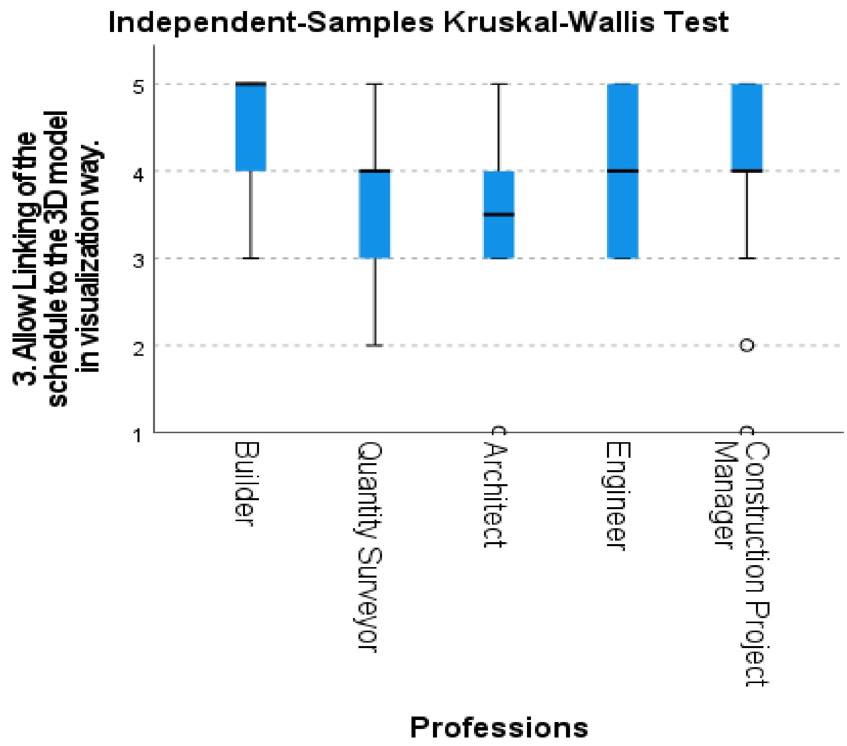


Figure 4.11 Graph showing the significant difference in BBSA3

Figure 4.12 explains further by showing the statistical weight of the nodes for each professional; these reveal the level at which each perspective was computed based on the survey data as plotted in Figure 4.11. This enables further statistical cross-pairwise comparison among the professionals.

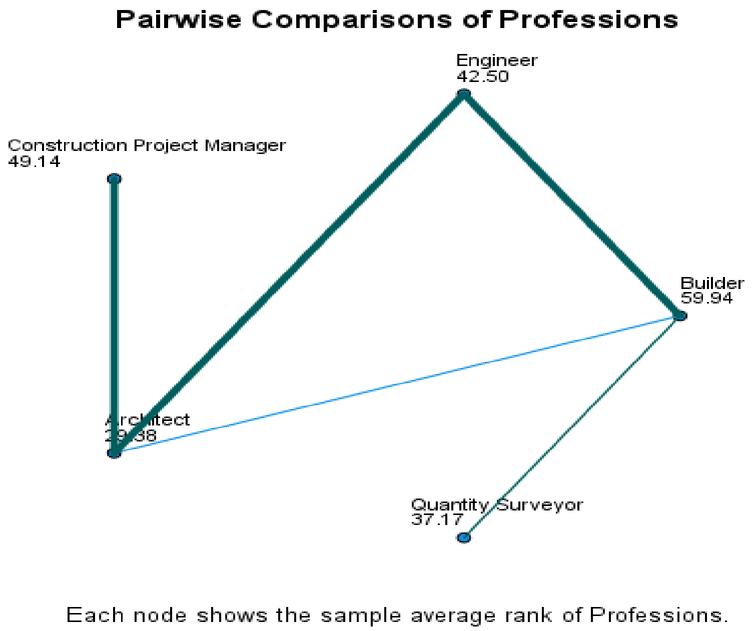


Figure 4.12 Node weight for the professionals

4.8.2 Pairwise Comparisons

After visualising the perspective rating and node weight of the professionals, it is best to proceed with the analysis. These will enhance the understanding of the statistical difference level for each professional. Thus, they were analysed using pairwise comparisons based on the professional's view. This reveals the statistically significant level. Table 4.13 presents the result of the pairwise comparison. Here, the following statistically significant parameters were extracted: Architect-Builder “0.004**”; Quantity Surveyor-Builder “0.009**”; Architect-Construction Project Manager “0.044*”; Engineer-Builder “0.047*”. In summary, these results show that the builders and construction project managers have experienced more of the said benefit (allowing linking of the schedule to the 3D model in a visualisation way) than every other professional since there is no significant difference in their perspectives. The graph in Figure 4.13 supports this assertion.

Table 4.13 Pairwise comparisons of professionals for BB3

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
Architect-Quantity Surveyor	7.792	10.980	.710	.478	1.000
Architect-Engineer	-13.125	10.980	-1.195	.232	1.000
Architect-Construction Project Manager	-19.764	9.803	-2.016	**.044***	.438
Architect-Builder	30.569	10.657	2.868	**.004****	.041
Quantity Surveyor-Engineer	-5.333	9.158	-.582	.560	1.000
Quantity Surveyor-Construction Project Manager	-11.972	7.708	-1.553	.120	1.000
Quantity Surveyor-Builder	22.778	8.768	2.598	**.009****	.094
Engineer-Construction Project Manager	-6.639	7.708	-.861	.389	1.000
Engineer-Builder	17.444	8.768	1.990	**.047***	.466
Construction Project Manager-Builder	10.806	7.240	1.492	.136	1.000
Note: Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050. (*) denote the Sig. level close to .050 (0.026-0.050), while (**) denote the Sig. level range from 0.001 to 0.025					

4.9 IMPACT OF BIM-T APPLICATION ON CONSTRUCTION AND MAINTENANCE PROJECT

4.9.1 Descriptive Analysis (Impact of BIM)

The adoption of BIM over the years has demonstrated remarkable impacts on construction and maintenance projects. This study identified 17 BIM impacts that were subjected to a survey among the SACPCMP. The relative importance index (RII) and factor analysis were conducted. A reliability check was conducted to validate the 5-point Likert scale using SPSS. The Cronbach alpha result, as shown in Table 3.8, was computed with SPSS. Having a total of 0.961 indicated that the 5-point Likert scale used is statistically reliable, which can be subject to further analysis. The result of the descriptive analysis in Table 4.15 indicated that the respondent strongly agreed that 94.12% (16) of the 17 identified impacts are realistic and agrees that BI14 is also realistic with the implementation of BIM in construction projects. The MIS ranges from 3.95 to 4.36, and the RII values range from 0.79 to 0.87. Table 4.14 is used to rate the importance level of each variable.

Table 4.14 Impact RII value

RII values	Importance level	Code
0.81 to 1.00	Strongly Agree	STA
0.61 to 0.80	Agree	A
0.41 to 0.60	Averagely Agree	AA
0.21 to 0.40	Disagree	D
0.00 to 0.20	Strongly disagree	SD

Table 4.15 Descriptive statistics of BIM impact (South Africa)

Descriptive Statistics n=101					
Variable Coding	Mean	Std. Dev.	RII	Ranking	Criticality level
BI1	4.07	1.025	.81	16th	STA
BI2	4.36	.846	.87	1st	STA
BI3	4.18	.925	.84	7th	STA
BI4	3.95	.976	.79	17th	A
BI5	4.13	.963	.83	11th	STA
BI6	4.16	.905	.83	9th	STA
BI7	4.22	.959	.84	5th	STA
BI8	4.08	.963	.82	15th	STA
BI9	4.10	.915	.82	14th	STA
BI10	4.16	.929	.83	10th	STA
BI11	4.27	.891	.85	3rd	STA
BI12	4.28	.906	.86	2nd	STA
BI13	4.12	.970	.82	12th	STA
BI14	4.22	.947	.84	4th	STA
BI15	4.12	1.036	.82	13th	STA
BI16	4.17	.990	.83	8th	STA
BI17	4.22	.959	.84	5th	STA

4.9.2 Factor Analysis (Impact of BIM)

For this section, the extraction method used is PCA using oblimin. The Kaiser normalisation rotation method was used on the 17 variables. Table 4.16 shows the correlation matrix; the value extracted is .747, greater than .32. Therefore, oblimin rotation can be adopted for clustering.

Table 4.16 BIM Impact component correlation matrix

Component Correlation Matrix

Component	1	2
1	1.000	.747
2	.747	1.000

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalisation.

Figure 4.13 shows that two components with eigenvalues greater than 1.0 were extracted, with the variance explained by each component. Component 1 contributed 61.998% and Component 2 contributed 5.598%. Altogether, the two components explained summed up 67.596% of the variability in the original 17 BIM impacts for the construction and post-construction stages in the South African construction industry. Papandrea *et al*. (2020) stated that 50% and above are acceptable to conduct PCA. Thus, this result meets the assumption for further PCA analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	10.540	61.998	61.998	10.540	61.998	61.998	5.814	34.201	34.201
2	1.952	5.598	67.596	1.952	5.598	67.596	5.677	33.395	67.596
3	.994	4.080	71.676						
4	.806	3.565	75.241						
5	.764	3.318	78.560						
6	.668	2.754	81.314						
7	.527	2.514	83.828						
8	.409	2.408	86.236						
9	.390	2.297	88.533						
10	.363	2.133	90.665						
11	.353	2.074	92.740						
12	.302	1.774	94.514						
13	.269	1.583	96.097						
14	.233	1.370	97.467						
15	.159	.938	98.405						
16	.150	.884	99.289						
17	.121	.711	100.000						

Extraction Method: Principal Component Analysis.

Figure 4.13 Rotated variance explained (BIM Impact)

The two extracted component groupings for the BIM impact variables surveyed among South Africa's built environment professionals were named and coded as shown in Table 4.17. The alpha α value calculated is very strong. This indicated a strong correlation between each variable in the grouped component.

Table 4.17 BIM Impact Group Naming

Component naming	BIM derivable impact	Variable Code	Factor Loading	Alpha α
Component 1				
Design and Profit related impact	Improve ROI	BI1	.875	.928
	Ease of Design Discrepancy and Omission Detection.	BI11	.858	
	Enhance Design Self-Confidence.	BI10	.846	
	Eradicate Design Clashes Amid Professionals and Contractors.	BI7	.825	
	Enhance the virtual design of the existing building and its components	BI13	.820	
	Enhance Management of Construction Credentials in Respect to Early Collaboration.	BI9	.779	
	Improved Quality Design and Productivity.	BI2	.740	
	Improve day-to-day construction work progress and ease of tracking construction activities.	BI6	.732	
Component 2				
Planning and Management related impact	Improve Client Brief Drafting.	BI17	.870	.925
	Improve maintenance Efficiency and Safety of Works.	BI16	.856	
	Decreased Risk and Cost Incurred by Contractor and Subcontractors in a Project.	BI15	.851	
	Improve Construction, maintenance, Scheduling/Planning.	BI14	.824	
	Eliminate/Reduce Design Errors.	BI2	.816	
	Overall Project Cost Reduction	BI4	.798	
	Enhance Scheduling of Work.	BI5	.773	
	Enhance project speed and save time.	BI3	.766	
	Improved Level of Readiness for Emergency Occurrence (Enhance Safety)	BI8	.730	

Figure 4.14 depicts the correlation between the component factor plot and how the variables are plotted to generate the component construct. It shows the relationship between the variables as perceived by the respondent.

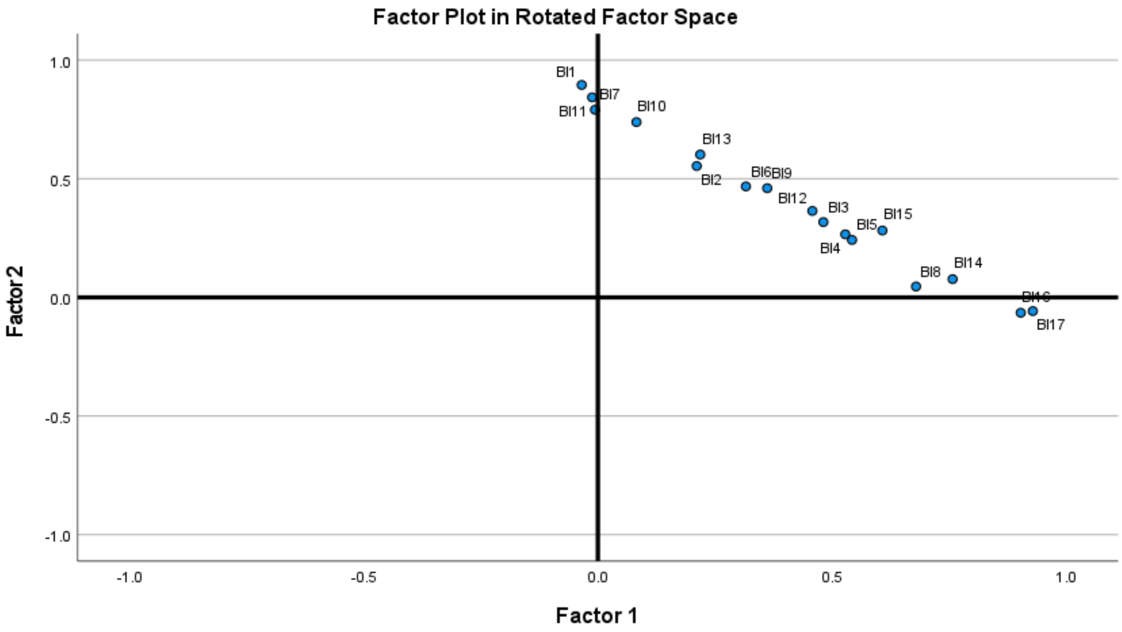


Figure 4.14 Correlation of rotated factor plot

Design and Profit-related Impact

The result of the clustered variables in component 1 is named the design and profit-related BIM impact. They are regarded as a collection of immeasurable contributions practically realised during the predesign, design, and construction phases. These were accomplished by embracing and implementing BIM in the construction industry (Toyin and Mewomo, 2023). This set of components comprises eight variables with a high factor loading varying from 0.721- 0.868. With a factor loading of 0.868, "Improve ROI" has the highest factor loading and “Improve Day-To-Day Construction Work Progress and Ease of Tracking Construction Activities”, with a factor loading of 0.721 has the lowest. Such high parameters imply that all the variables clustered in this component are highly correlated. Therefore, it can be assumed that the professionals deemed it important; this could be seen in the high mean score computed.

Planning and Management related BIM Impact

The items found in this component are related to planning and management impacts derived from the application of BIM based on the professionals' opinions and familiarity with BIM. They agreed that the variables in this component are part of the practical contributions derived from the adoption and implementation of BIM in the construction and post-construction phases of building projects. They had factor loadings ranging from 0.716 to 0.883. The planning-related variables such as Improving Client Brief Drafting, Improving Construction Scheduling/Planning and Enhancing Work Schedule are impacts that benefit both the client and contractors. Mesároš *et al*. (2020); Nawaz *et al*. (2021), and Toyin and Mewomo (2023) noted those variables as driving forces that promote the adoption and application of BIM in the design and construction phases of building production.

CHAPTER FIVE: DATA ANALYSIS, RESULTS PRESENTATION AND DISCUSSION: NIGERIAN

5.1 INTRODUCTION

This chapter analyses survey data from the Nigerian construction industry and discusses the findings in line with the literature. As explained in Chapter Three, the listed analysis in Table 3.4 were used in the analysis of data. Results are presented in Tables, Figures and Charts for clarity.

5.2 DEMOGRAPHIC INFORMATION OF RESPONDENTS

As illustrated in Figure 5.1, the survey generated 279 completed respondent inputs from the built environment professionals in Lagos State, Nigeria. The initial screening eliminated seven respondent inputs since the respondents indicated they were unaware of BIM technology. Thus, 272 valid responses passed the initial screening. 207 (76.10%) were male, and 65 (23.90 %) were female. The valid response rate recorded for this study is above the valid response of Olanrewaju *et al.* (2020), who generated 90 valid responses from the built environment professionals in Lagos.

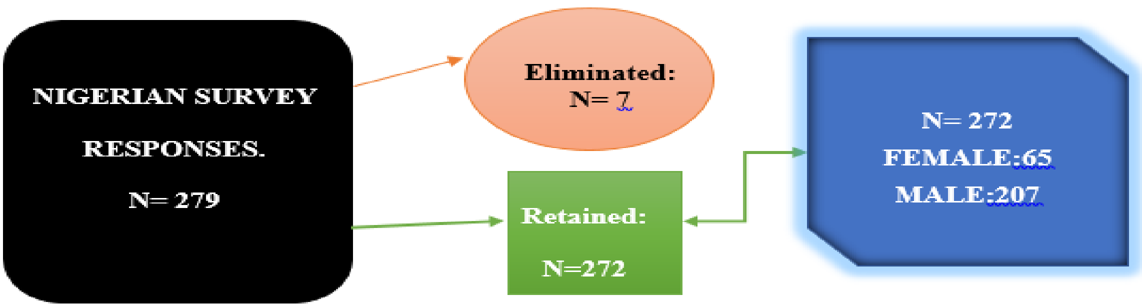


Figure 5.1 Respondents' gender distribution

From the survey report, as seen in Figure 5.2, over 52% of the respondents had second and third degrees, while the rest fell within the first degree at the time of conducting this survey. This implies that Nigerian built environment professionals are academically knowledgeable. Thus, an innovative understanding of technology should not be an issue.

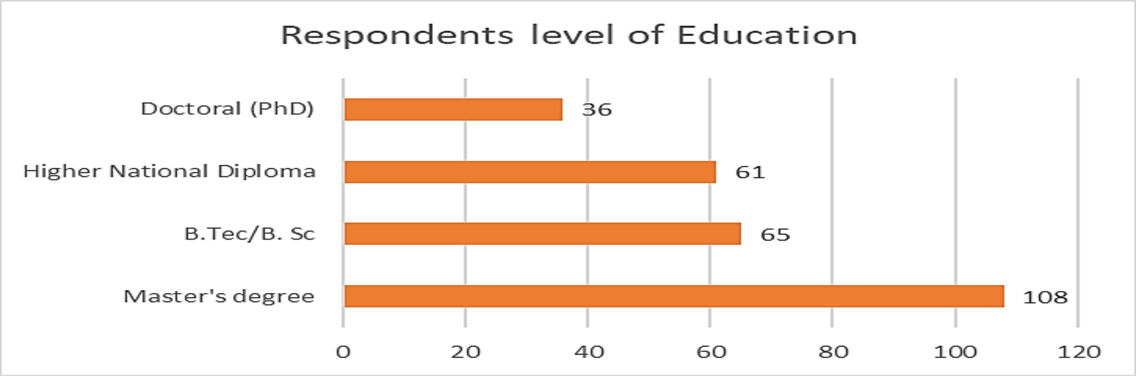


Figure 5.2 Education level

The categories of the professionals are displayed in Figure 5.3. This shows balanced inputs from the major built environment professionals in the Nigeria-built environment, with each having over 22% input. This means there is no significant difference in their information, which will strengthen the results since each professional's opinion could be seen in a more balanced form. This is similar to Olanrewaju *et al.*'s (2021) result, where the professionals sampled had nearly balanced inputs from 15% to 22%.

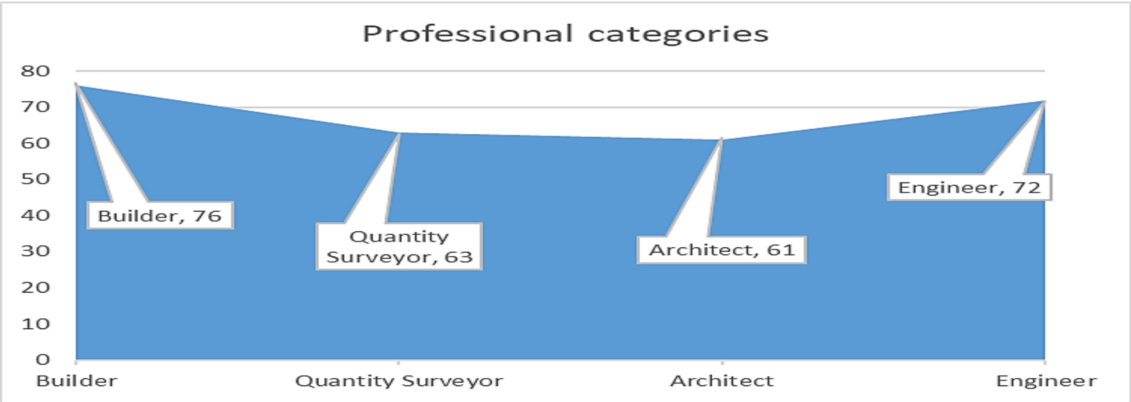


Figure 5.3 Categories of professional

As reported in Figure 5.4, 35.3% of professionals had 1-10 years' work experience in the industry. This could be traced to the catch them young policy practised among the Nigerian construction industry professional bodies. This policy enabled a quick induction of first-degree graduates into the professional body.

Moreover, over 60% (64.7%) had 11-20 years of working experience at the time of the survey. The experience level indicates that the survey participants can draw a credible and reliable conclusion. Van Roy and Firdaus (2020) opined that having over 11 years of working experience in a particular field is enough to assume a better understanding of the task.

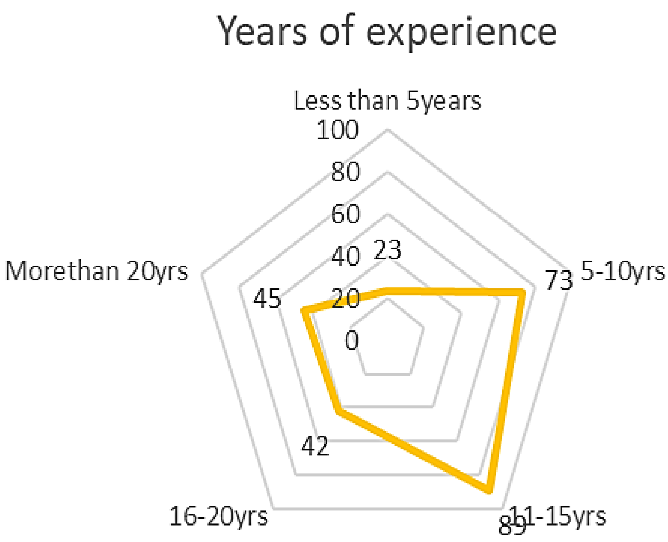


Figure 5.4 Years of experience See comment

5.3 LEVEL OF INVOLVEMENT IN BUILDING PRODUCTION

The respondent was asked to rate their level of involvement in building life cycle stages. Using the 5-point Likert scale as presented in Table 3.3, Table 5.1 shows that Builders are much more involved in the construction and post-construction stages than other professionals, with 4.42 and 3.26, respectively. The Architect indicated they had been more engaged in the design stage than other professionals, with an MIS of 4.36. From Table 5.1, Builders had the least engagement in the design stage with MIS 3.74. At the construction and post-construction stages, the Architect had the lowest MIS of 3.21 and 2.21, respectively. Based on the Architect's results, it could be concluded that they were less involved in the construction and post-construction stages than other professionals.

Table 5.1 Level of involvement in building production stages

Profession	Design stage		Construction stage		Post-construction stage	
	Mean	SD	Mean	SD	Mean	SD
Builder (N=76)	*3.74*	.957	**4.42**	1.156	**3.26**	1.280
Quantity Surveyor (N=63)	4.08	1.013	3.71	1. 049	2.45	1.003
Architect (N=61)	**4.36**	.913	*3.21*	.819	*2.21*	.990
Engineer (72)	4.14	.902	4.28	1.015	2.71	1.198

5.4 BIM AWARENESS AND USAGE LEVEL AMONG PROFESSIONALS

The result of this research survey found that seven out of the initial 279 respondents indicated that they are not aware of BIM technology. This indicated that over 97% of the professionals are aware of BIM. This is in contrast with Akerele and Etiene (2016), who conclude that the built environment professionals in Nigeria possess low awareness of BIM use in the construction industry. Therefore, this study retained 272 respondents who attested that they are aware of BIM and have knowledge of some BIM tools. All these respondents indicated that they have been able to apply or use BIM for construction work. Figure 5.5 shows the level at which the respondent used BIM across the construction phases.

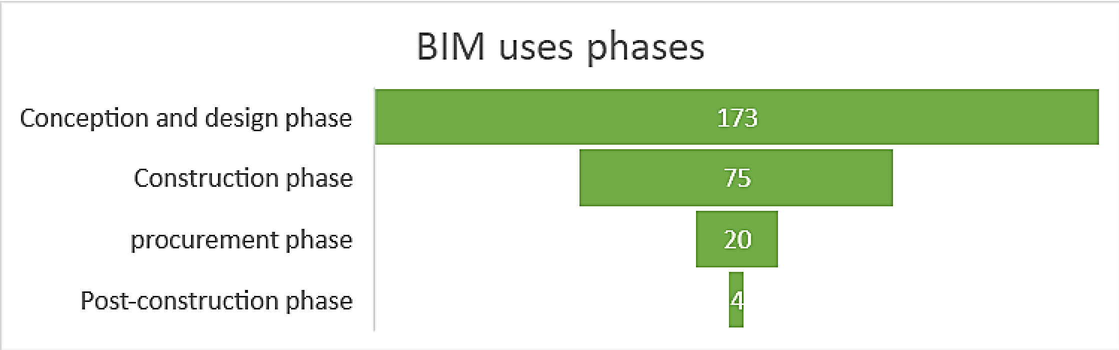


Figure 5.5 Rate of BIM Use Comment

5.4.1 Level of BIM Awareness

Regarding the level of awareness, all the results presented are normally distributed based on the 5-point Likert scale used, as presented in Table 5.2. However, the skewness was comprised of right and left skewness. Figure 5.6 shows the respondents' opinion distribution across the 5-point Likert scale. BAN 7, BAN1, BAN2, BAN6, and BAN5 have a high rating between MIS of 4.12 and 4.26. Thus, BAS3: "Government adopt BIM-T use for public sector building construction in Nigeria" was ranked last with a low mean score of 2.69. This means that more work is still needed from the government; they need to look into the enforcement of the technology in the country, as it has been done in developed countries. This is in tandem with the conclusions of Toyin and Mewomo (2022a); Olanrewaju *et al*. (2020); Onungwa and Uduma-Olugu (2017); Olanrewaju *et al*. (2021) and Saka and Chan (2020), who have studied within the Nigerian built environment. Their results assumed that the government still lags in implementing BIM in the country.

Table 5.2 Level of BIM Awareness Nigeria

Descriptive Statistics						
Coding	Mean	Std. Dev.	Variance	Skewness	Kurtosis	Distribution
BAN7	4.26	.839	.705	-.909	.018	Normal distribution
BAN1	4.26	.794	.631	-1.000	.906	Normal distribution
BAN2	4.21	.840	.705	-.827	-.039	Normal distribution
BAN6	4.14	.884	.782	-.915	.506	Normal distribution
BAN5	4.12	.907	.832	-.959	.648	Normal distribution
BAN4	3.01	1.007	1.015	.196	-.540	Normal distribution
BAN3	2.69	.871	.759	.433	.056	Normal distribution

Figure 5.6 shows the sample of the distribution in this section (normal distribution), which was extracted from the survey result data and generated using SPSS 27. These display the histogram chart of how respondents rate their opinions on the 5-point Likert scale.

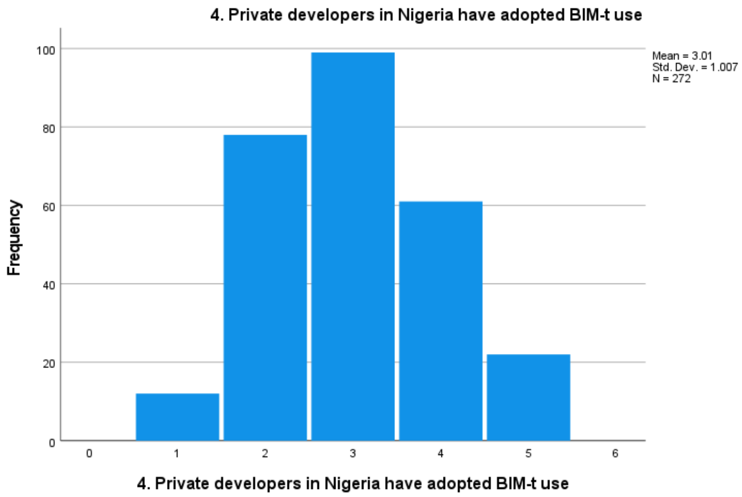


Figure 5.6 Respondent rating normal distribution

5.4.2 Usage of BIM Tools

Table 5.3 shows the tools frequently used by built environment professionals in the construction industry. However, each profession has BIM tools that are critical in discharging their duties—using the rating in Table 3.5 for ranking the usage level. Table 5.3 presents the statistical results of the data generated from the survey conducted in Nigeria. The respondents were asked to rate their level of usage in the 33 BIM tools on a 5-point Likert scale, as indicated in Table 3.3. The statistical survey result presented in Table 5.3 deduced that 2 out of the 33 BIM tools' usage is rated as "Very High" among the Nigerian built environment professionals AutoCAD and

Microsoft Project with MIS of 4.26 and 4.03 and ranked 1st and 2nd respectively. This is in line with the findings of Duarte-Vidal *et al*. (2021), where the author identified AutoCAD as an essential 2D and 3D BIM tool in the early introduction of BIM to the construction industry. The following were rated "High": Revit, SketchUp, ArchiCAD, Vectorworks Architect, and Autodesk BIM 360. A recent study by Vignali *et al*. (2021) used Autodesk BIM 360, AutoCAD and Revit to manage the project. This shows that the high rating of those tools can be traced to their versatile functionality.

Moreover, the rest are still within the average level of usage. It could be concluded that there is an increase in the use of BIM technology among professionals since only 2.5% of the 279 respondents indicated they were unaware of BIM and had not used any BIM tools. Thus, the seven participants were removed from the analysis, N=272.

Table 5.3 Level of BIM-T tools usage in Nigeria

Descriptive Statistics N=272	Mean	Std. DeV.	RII	Level	Ranking
1. Vectorworks Architect	3.19	1.196	.64	H	6th
2. ArchiCAD	3.59	1.055	.72	H	5th
3. Autodesk BIM 360	3.18	1.084	.64	H	7th
4. SketchUp	3.76	1.015	.75	H	4th
5. Revit	3.77	1.049	.75	H	3rd
6. Navisworks	2.99	1.159	.60	A	9th
7. Revizto	2.87	1.152	.57	A	11th
8. Iris VR	2.85	1.221	.57	A	12th
9. BEXEL manager	2.79	1.147	.56	A	15th
10. Edificius	2.70	1.213	.54	A	21st
11. ArCADia BIM 11	2.81	1.188	.56	A	14th
12. VisualARQ	2.78	1.183	.56	A	16th
13. Midas Gen	2.74	1.231	.55	A	18th
14. Civil 3D	3.02	1.157	.60	A	8th
15. Buildertrend	2.93	1.244	.59	A	10th
16. Hevacomp	2.59	1.187	.52	A	29th
17. Sefaria	2.67	1.209	.53	A	25th
18. BIMx	2.78	1.217	.56	A	17th
19. AutoCad	4.26	.947	.85	V	1st
20. Bently Architecture	2.68	1.154	.54	A	22nd
21. Computerised Maintenance Management System (CMMS)	2.67	1.168	.53	A	26th
22. Computer-Aided Facility Management (CAFM)	2.57	1.266	.51	A	32nd
23. Integrated Workplace Management (IWMS)	2.58	1.200	.52	A	31st

Descriptive Statistics N=272	Mean	Std. DeV.	RII	Level	Ranking
24. Building Automation System (BAS)	2.72	1.227	.54	A	20th
25. Synchro Professional	2.61	1.131	.52	A	28th
26. Vico Control	2.68	1.207	.54	A	23rd
27. Visual Application	2.68	1.232	.54	A	24th
28. D Profiler	2.64	1.188	.53	A	28th
29. Vico Takeoff Manager	2.72	1.154	.54	A	19th
30. QTO	2.41	1.193	.48	A	33rd
31. Navisworks Manager	2.66	1.164	.53	A	27th
32. Microsoft Project	4.03	1.141	.81	V	2nd
33. Navisworks simulate	2.83	1.090	.57	A	13th

5.5 USES OF BIM-T FOR MAINTENANCE: PROFESSIONALS' PERSPECTIVE

Based on the focus area of this study, it is essential to check the professionals' perspective towards using BIM-T for the post-construction stage.

5.5.1 Descriptive Analysis (BIM Use)

As explained in Section 4.5.1, the findings in Table 5.4 show that BU5: "Is used to easy maintenance work processes and effective asset management". It was ranked 1st with an MIS of 4.07 and RII of 0.81 and strongly agreed by all the professionals. This was in line with the agreement postulated by the facility managers who adopted BIM for facility management, as reported in the study by Cheng *et al*. (2020) and Chen *et al*. (2018a). The authors reported that the facility manager sees BIM as the brain behind information management, which assisted them in scheduling proper maintenance activities. Table 5.4, on the other hand, shows each professional's opinion rating. BUN1: "It is used to facilitate the integration of building facility data into BIM-T databases and display the drawing of such component" was ranked 6th of 6 in this table, with a MIS of 3.95 and RII of 0.79. In general, all the professionals agreed with BIM's uses for maintenance. The MIS ranges from 3.75 to 4.27. Therefore, this study concurs with other related studies (Cheng *et al*., 2020; Chen *et al*., 2018a; Okoro *et al*., 2020;

Edirisinghe *et al*., 2017; Arayici *et al*., 2012) which identify those variables as significant uses of BIM for facility management.

Table 5.4 BIM used for maintenance

Descriptive						
Coding	Professionals	N	Mean	Std. Dev.	RII	Ranking
BUN1	Builder	76	3.97	.966		
	Quantity Surveyor	63	4.08	1.036		
	Architect	61	3.85	1.046		
	Engineer	72	3.90	1.064		
	Total	272	3.95	1.024	0.79	6th
BUN2	Builder	76	3.93	.869		
	Quantity Surveyor	63	3.97	.915		
	Architect	61	3.93	.873		
	Engineer	72	4.14	.893		
	Total	272	4.00	.887	0.80	4th
BUN3	Builder	76	3.96	.916		
	Quantity Surveyor	63	4.02	.871		
	Architect	61	3.95	1.056		
	Engineer	72	4.04	.863		
	Total	272	3.99	.921	0.80	5th
BUN4	Builder	76	4.13	.806		
	Quantity Surveyor	63	4.19	.780		
	Architect	61	3.75	.943		
	Engineer	72	4.03	.964		
	Total	272	4.03	.886	0.81	3rd
BUN5	Builder	76	4.04	.916		
	Quantity Surveyor	63	4.27	.954		
	Architect	61	3.92	1.130		
	Engineer	72	4.04	1.013		
	Total	272	4.07	1.003	0.81	1st
BUN6	Builder	76	3.99	.959		
	Quantity Surveyor	63	3.94	.965		
	Architect	61	4.15	.813		
	Engineer	72	4.14	.827		
	Total	272	4.05	.895	0.81	2nd

5.5.2 Inferential Analysis (BIM Use)

Based on the assumption stated in Section 4.5.2 and the result in Table 5.5, the Sig. values indicated a level of equal variance across the board. Since there is an acceptable level of equal variance across the board (Table 5.5), a one-way ANOVA can be computed.

Table 5.5 Variance homogeneity test

Coding		Levene Statistic	df1	df2	Sig.
BUN1	Based on Mean	.384	3	268	.765
	Based on Median	.151	3	268	.929
	Based on Median and with adjusted df	.151	3	262.236	.929
	Based on trimmed mean	.268	3	268	.848
BUN2	Based on Mean	.356	3	268	.785
	Based on Median	.371	3	268	.774
	Based on Median and with adjusted df	.371	3	261.308	.774
	Based on trimmed mean	.577	3	268	.630
BUN3	Based on Mean	1.454	3	268	.227
	Based on Median	1.262	3	268	.288
	Based on Median and with adjusted df	1.262	3	263.209	.288
	Based on trimmed mean	1.046	3	268	.372
BUN4	Based on Mean	1.146	3	268	.331
	Based on Median	1.016	3	268	.386
	Based on Median and with adjusted df	1.016	3	260.565	.386
	Based on trimmed mean	.949	3	268	.418
BUN5	Based on Mean	1.696	3	268	.168
	Based on Median	1.157	3	268	.327
	Based on Median and with adjusted df	1.157	3	209.214	.327
	Based on trimmed mean	1.371	3	268	.252
BUN6	Based on Mean	1.037	3	268	.377
	Based on Median	1.246	3	268	.293
	Based on Median and with adjusted df	1.246	3	266.360	.293
	Based on trimmed mean	.782	3	268	.505

As previously explained in Section 4.5.2, the one-way ANOVA result presented in Table 5.6 shows that the BUN4 sig. value of 0.029 is less than 0.05; this means there is a significant difference between the perspectives of two or more professionals. As suggested by Johnson, (2022) and Kim (2017), the opinions of two or more of the respondent categories are perceived to have a different level of agreement. To further understand where the difference in the level of agreement comes from, it is expected to conduct a post-hoc "Multiple Comparisons" test using Tukey HSD. This method has been employed by a management-related study conducted in Nigeria (Toyin and Mewomo, 2022b). The result presented in Table 5.7 indicated that the quantity surveyor and architect have statistically different opinions on the agreement on the BUN4 variable: "It is used to store inspections and repair information history carried out on the facilities". These could be traced to their level of involvement in the maintenance stage of the building presented in this study. Their mean score in Table 5.1 shows that quantity surveyors are more involved in the post-construction stage than Architects. This could contribute to the significant difference in their opinions about the BUN4 variable. The completion of Table 5.7 and be seen in Appendix 8.

Table 5.6 ANOVA result BIM uses

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
1. It is used to facilitate integrating building facility data into BIM-T databases and display the drawing of such components.	Between Groups	1.837	3	.612	.581	.628
	Within Groups	282.542	268	1.054		
	Total	284.379	271			
2. It is used to plan maintenance routes (Predictive and Preventive)	Between Groups	2.040	3	.680	.864	.460
	Within Groups	210.956	268	.787		
	Total	212.996	271			
3. BIM-T enables the building facility manager to perform Maintenance work orders through prompt scheduling automatically.	Between Groups	.392	3	.131	.153	.928
	Within Groups	229.593	268	.857		
	Total	229.985	271			
4. It is used to store inspections and repairs	Between Groups	7.048	3	2.349	3.061	.029

information history carried out on the facilities.	Within Groups	205.654	268	.767		
	Total	212.702	271			
5. It is used to ease maintenance work processes and effective asset management.	Between Groups	4.049	3	1.350	1.346	.260
	Within Groups	268.759	268	1.003		
	Total	272.809	271			
6. BIM-T use help to facilitate locating of building elements and component, which allows for better inspection and management.	Between Groups	2.263	3	.754	.940	.422
	Within Groups	215.016	268	.802		
	Total	217.279	271			

Table 5.7 BIM uses post-hoc comparisons result

Multiple Comparisons					
Tukey HSD					
Dependable Variable	(I)	(J)	Mean Difference (I-J)	Std. Error	Sig.
4. It is used to store inspection and repair information on the facilities.	Builder	Quantity Surveyor	-.059	.149	.979
		Architect	.377	.151	.061
		Engineer	.104	.144	.889
	Quantity Surveyor	Builder	.059	.149	.979
		Architect	.436*	.157	.030
		Engineer	.163	.151	.704
	Architect	Builder	-.377	.151	.061
		Quantity Surveyor	-.436*	.157	.030
		Engineer	-.274	.152	.278
	Engineer	Builder	-.104	.144	.889
		Quantity Surveyor	-.163	.151	.704
		Architect	.274	.152	.278
Note: The (*) indicate where there is Sig. difference between the mean score of the professionals					

5.6 BARRIERS HINDERING THE APPLICATION OF BIM

5.6.1 Descriptive Analysis (BIM Barriers)

Based on the description in Section 4.6.1, this section uses the same procedure to analyse and discuss the barriers. MIS, RII, and standard deviation were used to rank the variables. Table 4.8 shows the rating levels. Table 5.8 shows that only two barriers are deemed very critical, namely: “Low computer skills among some construction professionals and lack of familiarity with BIM capacity: BBN1 and BBN2” while the remaining barriers fall within the critical level. Based on these findings, it can be concluded that all the barriers are related to the Nigerian construction industry. Therefore, there is a need to look for additional ways to explain the variables in a simpler analytical method by grouping them into component clusters.

Table 5.8 BIM barriers rating

Descriptive Statistics N=272					
Barriers Coding	Mean	Std. Dev.	RII	Criticality Level	Ranking
BCN1	4.07	.958	.81	VC	1st
BCN2	4.04	.909	.81	VC	2nd
BCN33	3.86	.954	.77	C	3rd
BCN32	3.84	.976	.77	C	4th
BCN4	3.84	1.003	.77	C	5th
BCN13	3.81	1.044	.76	C	6th
BCN26	3.81	.981	.76	C	7th
BCN9	3.79	.992	.76	C	8th
BCN19	3.79	1.033	.76	C	9th
BCN28	3.78	.972	.76	C	10th
BCN12	3.76	.975	.75	C	11th
BCN11	3.76	1.062	.75	C	12th
BCN30	3.74	1.025	.75	C	13th
BCN20	3.74	1.036	.75	C	14th
BCN5	3.73	1.038	.75	C	15th
BCN21	3.71	1.041	.74	C	16th
BCN7	3.71	.971	.74	C	17th
BCN23	3.70	1.079	.74	C	18th
BCN3	3.70	.978	.74	C	19th
BCN27	3.69	.995	.74	C	20th
BCN25	3.69	1.035	.74	C	21st
BCN24	3.69	1.032	.74	C	22nd
BCN6	3.67	1.067	.73	C	23rd
BCN15	3.66	1.026	.73	C	24th
BCN31	3.65	.971	.73	C	25th
BCN16	3.64	1.111	.73	C	26th
BCN10	3.63	1.047	.73	C	27th
BCN22	3.61	1.036	.72	C	28th
BCN14	3.58	1.117	.72	C	29th
BCN8	3.57	1.204	.71	C	30th
B CN18	3.56	1.129	.71	C	31st
BCN17	3.53	1.110	.71	C	32nd
BCN29	3.53	1.048	.71	C	33rd

5.6.2 Factor Analysis (BIM Barriers)

This section follows the steps in Section 4.6.2 to conduct factor analysis; it also uses the PCA extraction method on the data generated from Nigeria based on the 33 identified barriers. As seen in Table 3.7, this study adopted .40 for its factor loading since it has a valid response rate of 272. Table 3.7 shows the guideline criteria adopted to conduct PCA on the 33 variables. In addition, the result of the calculation of the required parameter for conducting PCA was included in the table under the column Nigeria. PCA: data reliability and adequacy verification.

For this study, the KMO test generated a 0.814 value, while Bartlett's test generated a statistically significant result of chi-square = 1881.715, p = 0.000, as seen in Table 3.7. Thus, the results meet the requirements of PCA.

5.6.2.1 Component correlation Matrix (CCM)

The explanation of CCM can be seen in Section 4.6.2. Table 5.9 shows the CCM results for this study's 33 barrier variables. The reason for showing this table is to check which rotation is adequate for the PCA. What to look out for in Table 5.9 CCM is to check any correlation between factors or components that is greater than .32 or less than -.32 in Table 5.9. There is no component greater than .32 or less than -.32 in Table 5.9. Therefore, orthogonal rotation can be adopted.

Table 5.9 BIM barriers component correlation Matrix result

Component	1	2	3	4	5	6	7	8	9
1	1.000	.077	.100	.112	.183	-.058	-.009	.113	.076
2	.077	1.000	.116	.049	.093	.095	.017	.151	.214
3	.100	.116	1.000	.188	.222	.020	.047	.148	.209
4	.112	.049	.188	1.000	.153	-.090	.024	.119	.084
5	.183	.093	.222	.153	1.000	-.003	.033	.134	.181
6	-.058	.095	.020	-.090	-.003	1.000	.013	.020	.078
7	-.009	.017	.047	.024	.033	.013	1.000	.002	.050
8	.113	.151	.148	.119	.134	.020	.002	1.000	.185
9	.076	.214	.209	.084	.181	.078	.050	.185	1.000

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalisation.

After the correlation matrix has been checked and the proper rotation method has been determined. Then the analysis proceeds further to the PCA proper using the varimax rotation method. The result of the variables' communalities shows a significant value which ranges from above 0.409. The value for each variable can be seen in Appendix 4.

Figure 5.7 shows that nine components with eigenvalues greater than 1.0 were extracted with the variance explained by each component. Component 1 contributed 17.830%, Component 2 contributed 7.241%, Component 3 contributed 5.329%, Component 4 contributed 4.859%, Component 5 contributed 3.986%, Component 6 contributed 3.681%, Component 7 contributed 3.634%, Component 8 contributed 3.516% and Component 9 contributed 3.354%. Altogether, the nine components explained summed up to 53.432% of the variability in the original 33 barriers to the application of BIM in the Nigerian construction industry. Based on the assumption in Section 4.6.2.2 this result meets the minimum requirement to conduct rotated component analyses in PCA.

Total Variance Explained

Component	Initial Eigenvalues Total	Initial Eigenvalues % of Variance	Initial Eigenvalues Cumulative %	Extraction Sums of Squared Loadings Total	Extraction Sums of Squared Loadings % of Variance	Extraction Sums of Squared Loadings Cumulative %	Rotation Sums of Squared Loadings[a] Total
1	5.884	17.830	17.830	5.884	17.830	17.830	2.342
2	2.390	7.241	25.072	2.390	7.241	25.072	2.491
3	1.759	5.329	30.401	1.759	5.329	30.401	3.224
4	1.604	4.859	35.260	1.604	4.859	35.260	2.355
5	1.315	3.986	39.247	1.315	3.986	39.247	3.203
6	1.215	3.681	42.928	1.215	3.681	42.928	1.567
7	1.199	3.634	46.562	1.199	3.634	46.562	1.293
8	1.160	3.516	50.078	1.160	3.516	50.078	2.307
9	1.107	3.354	53.432	1.107	3.354	53.432	2.921
10	.968	2.933	56.364				
11	.960	2.911	59.275				
12	.935	2.833	62.108				
13	.885	2.681	64.789				
14	.847	2.568	67.357				
15	.821	2.489	69.846				
16	.793	2.402	72.249				
17	.739	2.239	74.488				
18	.730	2.213	76.701				
19	.695	2.105	78.806				
20	.667	2.021	80.827				
21	.646	1.958	82.785				
22	.617	1.871	84.657				
23	.609	1.846	86.503				
24	.542	1.642	88.145				
25	.527	1.596	89.741				
26	.494	1.497	91.238				
27	.483	1.465	92.702				
28	.453	1.371	94.074				
29	.426	1.292	95.366				
30	.407	1.233	96.598				
31	.400	1.212	97.811				
32	.366	1.109	98.919				
33	.357	1.081	100.000				

Extraction Method: Principal Component Analysis.

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.

Figure 5.7 Total variance explained on BIM application barriers

5.6.2.2 Scree Plot graph

Looking at the scree plot shown in Figure 5.8, the slope of the curve decreases as the explained variance flattens as each eigenvalue slowly reduces. The indication in Figure 5.8 shows that the extracted loadings generated nine factors. This was also shown in the scree plot. Thus, the number of factors obtained was the same as the number of data points above the broken line. Therefore, data points that fell directly on or below the broken line were not counted because an eigenvalue is a conventional approach for factor extraction (Nunayon *et al*., 2020); it was examined in this study for the same purpose. They are useful in developing criteria for keeping the essential elements to be addressed in factor analysis (K'Akumu *et al*., 2013). The criterion for evaluating important factors was an eigenvalue ≥ one—the scree plot in Figure 5.8 shows that the ultimate solution occurs at a location on the vertical axis where the eigenvalue equals one. This was determined after the nine data points were collected. It confirms that only nine components could be extracted.

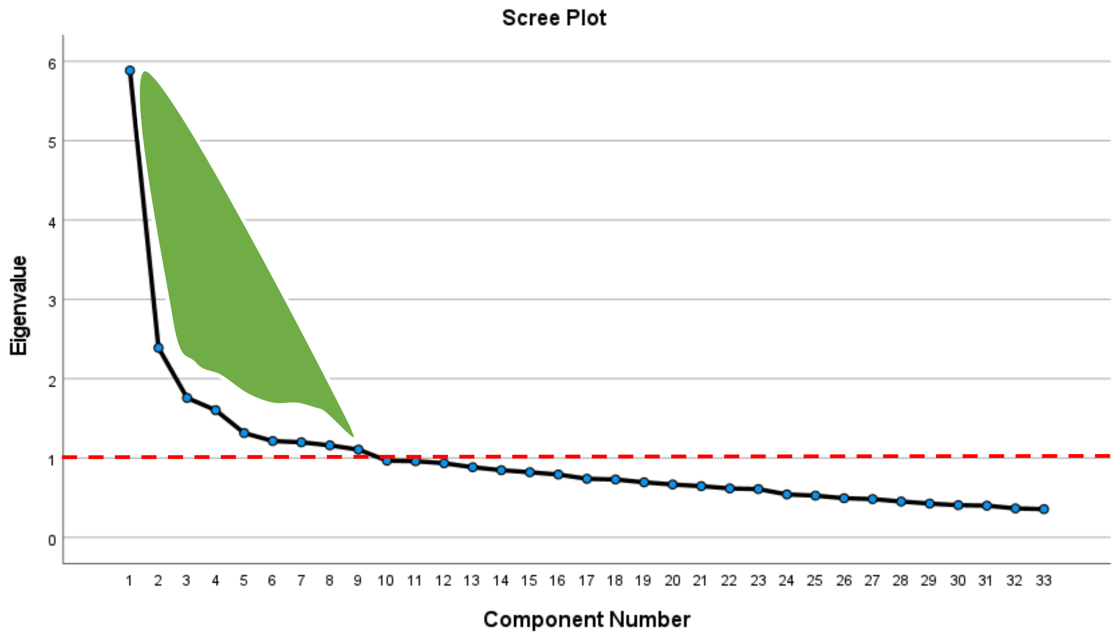


Figure 5.8 Total variance explained on BIM application barriers

5.6.2.3 Rotated component matrix

Based on the explanation in Section 4.6.2, the valid response was 272 for this study. Thus, the adequate significant level to retain from the PCA rotated component matrix is ≥ 0.40, as seen in Table 3.6. Table 5.10 shows the component name, variable code and Alpha value of the variable. The overall Cronbach's α value for the 33 variables is .853. Kumar (2018) opined that for the survey instrument to be reliable, the value of Cronbach's alpha must be greater than 0.65. Pallant (2020) recommends 0.7 Cronbach's α value as acceptable to conduct PCA. Therefore, this study's α value of .814 shows that the survey instrument used is reliable. Appendix 9 shows the result of the PCA rotation.

Table 5.10 Component and variables naming

Component naming	Code		Factor Loading	Alpha α
	Component 1			
Environmental Influence	BCN18		.678	.868
	BCN17		.596	
	BCN16		.570	
	BCN20		.568	
	BCN15		.537	
	Component 2			
Administrative-related factors	BCN10		.644	.868
	BCN13		.636	
	BCN12		.617	
	BCN14		.602	
	Component 3			
Legal related factor	BCN21		.598	.779
	BCN31		.588	
	BCN29		.507	
	BCN27		.505	
	Component 4			
Top management-related factor	BCN6		.667	.836
	BCN7		.660	
	BCN9		.560	
	BCN3		.506	
	Component 5			
Legal reason	BCN32		.716	.690
	BCN33		.644	
	Component 6			
Personnel related factor	BCN1		.771	.751
	BCN2		.727	
	BCN4		.504	
	Component 7			
Construction management circumstances	BCN26		.682	.725
	BCN28		.521	
	BCN30		.477	
	BCN22		.435	
	Component 8			
Financial Reasons	BCN5		-.568	.544
	BCN24		.538	
	BCN25		.434	
	Component 9			
Economic factor	BCN19		.670	.232
	BCN8		-.531	

Component 1: Environmental Influence

Site environmental influence refers to the limiting factors formed around the building site's geographical location. BIM adoption necessitates active professional engagement throughout the project's life cycle (Toyin and Mewomo, 2022c). However, the lack of authentic BIM tools and the unavailability of BIM data are significant environmental impediments that may inhibit the use of BIM. (Toyin and Mewomo, 2022a; Saka and Chan, 2021; Olanrewaju *et al*., 2020; Chan *et al*., 2019) see those barriers in this component as the hindrance caused by top management support and the nonchalant attitude expressed by the professional personnel. This component was classified in this study as follows: "complexity in getting used to BIM technology and procedures; the complex process of learning BIM technology; insufficient available BIM data; reluctancy/lack of knowledge sharing by firms that have successfully implemented BIM, and difficulties in getting a convenient time required for BIM training". Table 5.10 shows the parameters for these barriers.

Component 2: Administrative-related factor

Component 2 variables are associated with administrative negligence that could emanate from the top team leaders. These are their administration and coordination attitudes toward a broader application of BIM. These pose a significant challenge in the BIM market. The findings of Shin and Kim (2021) show that BIM professionals are ready to adopt the consequences of using BIM. The authors concluded that “administrative preparations are not available beforehand”. Subsequently, Olanrewaju *et al*. (2021) envisage that the faster BIM is accepted by the organisational governing body or professional regulatory body in Nigeria, the better the chances of getting BIM adopted for building production. Moreover, Leśniak *et al*. (2021), Shin and Kim (2021) see the need for a higher level of regulatory concern and the provision of administrative solutions for successful BIM applications. The barriers under this component identified in this study are: “negative attitude towards working collaboratively; inaccessibility to genuine BIM tools; lack of motivation to implement BIM in projects, and absence of adequate quantifiable digital design information”.

Components 3 and 5: Legal-related factors and legal reason

Legal-related factors have been discussed in Section 4.6.2.4.1. This component included the following categories: lack of organised BIM learning resources; absence of BIM-specific insurance; ambiguous exclusive ownership claims of BIM tool data, and an insurance foundation that is missing for BIM implementation. Legal impediments include a lack of awareness regarding BIM application principles and rules among some project professionals, as well as a lack of policymaker support. These barriers resonate with the laws that guide the parties involved in the project (Bouhmoud and Loudyi, 2021); this explains the customary rights of each party (Ahmed, 2018). The absence of support from policymakers will abort the legalisation of BIM in the country.

Component 5: Top management-related factor

Top management-related factors are the unsupportive attitudes that emanate from the circles of the team leaders or management board of an organisation towards innovative technology such as BIM. For BIM to be fully adopted or applied in any project, the management must show a high level of support and acceptance of the technology. Kekana *et al*. (2014) suggested that top managers should see the need to adopt BIM through its proven reliability and benefits to support the fast enforcement of BIM in South Africa. Also, the client must consent to the adoption and be ready to pay any extra charges that may ensue. Saka and Chan (2020) postulate that the need for clients to accept BIM will benefit small enterprises. This will enable them to be financially fit to hire the required BIM experts to manage the project. The following are the related barriers: Lack of support from senior leaders in the building business to accept BIM technology from the conventional technique of contracting; Inadequately developed practical strategies and standards; Lack of support from owners and management owing to a lack of understanding of BIM ideas; Resistance to change from the established way of design and construction.

Component 6: Personnel-related factors

The variables clustered in this component are attributed to the construction professional's knowledge of BIM capability and how to incorporate and adapt to BIM workstations. (Toyin and Mewomo, 2022a; Durdyev *et al*., 2021; Ahmed, 2018) identify personnel-related factors as the key factors driving the application of BIM in the construction industry. The following are grouped in this section: "Low computer skills among some construction professionals"-- this affects the personnel's ability to function well and easily transition between innovative technologies (Wu *et al*., 2021), and each personnel is expected to possess basic computer knowledge (Toyin and Mewomo, 2022a). "Lack of familiarity with BIM capacity" -- the inability of professionals to familiarise themselves with the capacity of BIM-- is a great challenge (Bouhmoud and Loudyi, 2021), which may discourage their acceptability. "Poor awareness of BIM benefits" -- when the benefits accruable with BIM adoption or the application is not well understood, it may prevent its use. As a result, it is incumbent on personnel to define means of correlating with innovative technology in the construction industry in order to remain relevant as the sector evolves.

Component 7: Construction management influences

The construction management influences are the driving motivation that aids the adoption and application of BIM in the construction industry. Under this component, four variables were clustered; this shows the barriers variable related to this component. The unwillingness of the government to support BIM use could sabotage the realisation of BIM in the country (Van Roy and Firdaus, 2020). The lack of proper protocols supporting market demand for BIM adoption is a significant barrier, as the construction business market needs to identify the necessity of BIM application (Ahmed, 2018).

Components 8 & 9: Financial reasons and Economic factors

In addition to cost-related hurdles, there are also financial and economic barriers. _ For example, the cost of inviting BIM experts to manage the project may increase the project's cost. It may be difficult to find convenient training times required for training professionals if the managers are not ready to release their workers due to the ongoing project they are managing (Olanrewaju *et al*., 2022). The lack of BIM experts on a construction project may pose many challenges to the teams and the project, such as cost overruns and a loss of interest in adopting BIM, among other factors. (Rodrigues and Lindhard, 2021). BIM managers' lack of knowledge may result in crucial information being lost during the building production process, which could have profound financial consequences (Olanrewaju *et al*., 2022).

5.7 BIM BENEFITS DERIVED DURING CONSTRUCTION AND POST-CONSTRUCTION

5.7.1 Kruskal-Wallis Test

This section uses the principles in Section 4.7.1. As seen in Table 5.11, the BB1 (increase digital representation) p-value is **0.042**. These violated the null hypothesis statement, thus rejecting the null hypothesis. The rest of the variables accept the null hypothesis test, meaning there is no significant difference in the professionals' perspectives on the various BIM benefits. Hecke (2012) and Al-Ashmori *et al*. (2020) noted that a significant statistical difference in the respondents' opinions would result in the rejection of the hypothesis under study.

Table 5.11 BIM benefits survey result hypothesis test

Variable code	Mean	Stv. Div.	Sig.[a,b]	Ranking	Decision
BB1	4.47	.601	.042*	1st	**Reject the null hypothesis.**
BB2	4.38	.748	.135	2nd	Retain the null hypothesis.
BB3	4.18	.843	.239	11th	Retain the null hypothesis.
BB4	4.35	.782	.264	3rd	Retain the null hypothesis.
BB5	4.23	.778	.947	9th	Retain the null hypothesis.
BB6	4.28	.747	.305	5th	Retain the null hypothesis.
BB7	4.26	.778	.659	6th	Retain the null hypothesis.
BB8	4.24	.785	.770	7th	Retain the null hypothesis.
BB9	4.21	.761	.323	10th	Retain the null hypothesis.
BB10	4.24	.831	.582	8th	Retain the null hypothesis.
BB11	4.18	.846	.882	12th	Retain the null hypothesis.
BB12	4.17	.830	.598	13th	Retain the null hypothesis.
BB13	4.30	.771	.421	4th	Retain the null hypothesis.

While conducting the Kruskal-Wallis test, it is essential to display the bar chart showing the perspective opinion of each rejected hypothesis. SPSS will automatically generate these. The graph in Figure 5.9 shows that the Builder's rating has a black bar at the tip of 5, while the rchitect's rating is between 4 and 3; this also shows the variations for other professionals. This suggests that architects and engineers valued this benefit (increased digital representation) more than builders and quantity surveyors.

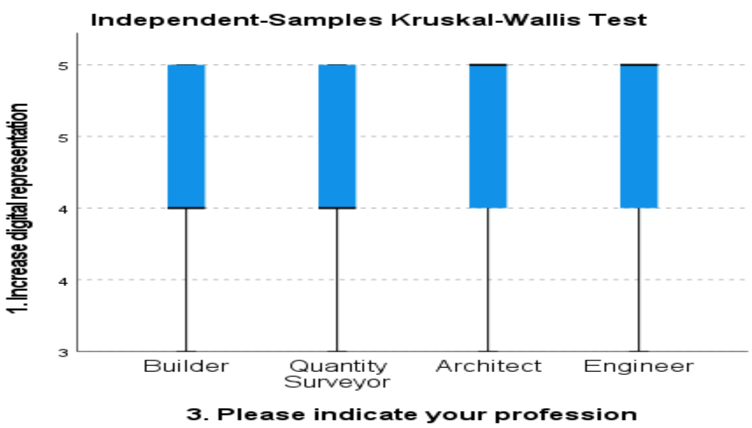


Figure 5.9 Graph showing the significant difference in BBN1

Figure 5.10 explains further by showing the statistical weight of the nodes for each professional; these reveal the level at which each perspective was computed based on the survey data as plotted in Figure 5.10. This enables further statistical cross-pairwise comparison among the professionals.

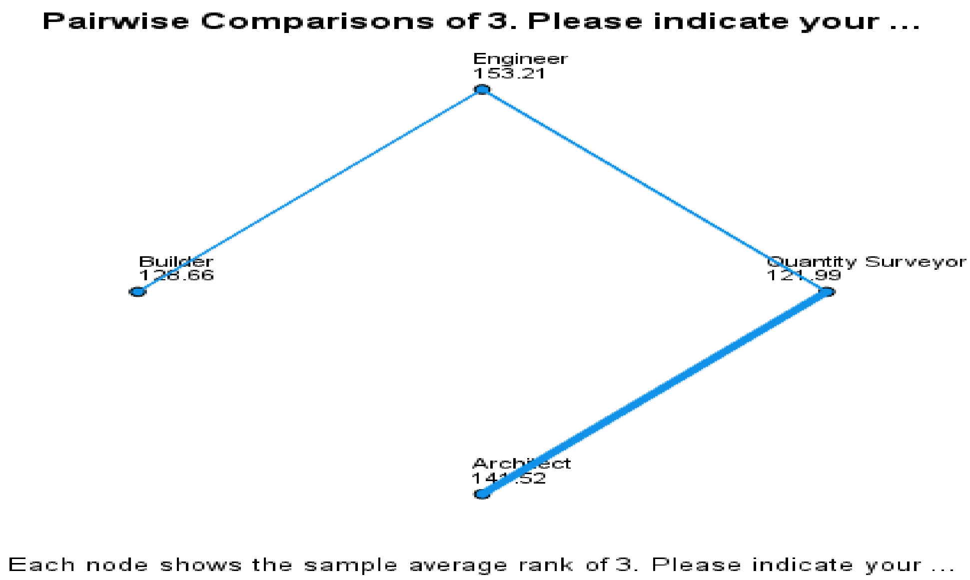


Figure 5.10 Node weight for the professionals

5.7.2 Pairwise Comparisons

After visualising the perspective rating and node weight of the professionals, it is best to proceed with the analysis. These will enhance understanding of the statistical difference level for each professional. Analysis should be based on cross-pairwise comparisons according to the professional's opinions. This will reveal the statistically significant level. Table 5.10 presents the result of the pairwise comparison. Here, the following statistically significant parameters could be extracted: Quantity Surveyor-Engineers “0.009**”; Builder-Engineer “0.032*”.

Nevertheless, this result shows a significant difference in the node weight deference of over 20 (24.55) for Builder-Engineer. While for Quantity Surveyor-Engineer, the node weight deference is 31.22 based on BB1 (increase digital representation). The graph in Figure 5.9

supports this. The weight of the Sig. value in Table 5.12 implies that the builder perceived more of the said benefit than the Quantity surveyor.

Table 5.12 Pairwise comparisons of professionals for BBN1

Quantity Surveyor-Builder	6.672	11.835	.564	.573	1.000
Quantity Surveyor-Architect	-19.533	12.478	-1.565	.117	.705
Quantity Surveyor-Engineer	-31.216	11.984	-2.605	.009**	.055
Builder-Architect	-12.860	11.941	-1.077	.281	1.000
Builder-Engineer	-24.544	11.424	-2.148	.032*	.190
Architect-Engineer	-11.684	12.088	-.967	.334	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .050.
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

5.8 IMPACT OF SUCCESSFUL BIM-T APPLICATION ON CONSTRUCTION AND MAINTENANCE PROJECT

5.8.1 Descriptive Analysis (Impact of BIM)

The results of the 17 identified BIM impacts subjected to a survey among Nigerian built environment professionals were processed using RII analysis and factor analysis. A reliability check was conducted to validate the 5-point Likert scale using SPSS. The Cronbach alpha result, as shown in Table 3.8, was computed at 0.815, indicating that the 5-point Likert scale used is statistically reliable and can be subjected to further analysis. The result of the descriptive analysis in Table 5.13 indicated that the respondent strongly agreed with all 17 identified impacts as being realistic with the implementation of BIM in construction projects. The MIS ranges from 4.13 to 4.43, and the RII value ranges from 0.83 to 0.89. This high rating could be traced to their level of usage of BIM tools, which is significantly above average, as seen in Table 5.6. Appendix 7 shows the naming of the variable coding.

Table 5.13 Descriptive statistics of BIM impact

Descriptive Statistics n=272					
Variable Coding	Mean	Std. Dev.	RII	Criticality level	Ranking
BIN8	4.13	.786	.83	STA	17th
BIN4	4.16	.844	.83	STA	16th
BIN13	4.17	.777	.83	STA	15th
BIN15	4.19	.817	.84	STA	14th
BIN5	4.20	.744	.84	STA	13th
BIN11	4.20	.810	.84	STA	12th
BIN3	4.21	.772	.84	STA	11th
BIN14	4.23	.768	.85	STA	10th
BIN9	4.24	.813	.85	STA	9th
BIN6	4.25	.756	.85	STA	8th
BIN7	4.26	.778	.85	STA	7th
BIN12	4.26	.838	.85	STA	6th
BIN16	4.27	.801	.85	STA	5th
BIN10	4.28	.765	.86	STA	4th
BIN1	4.32	.777	.86	STA	3rd
BIN17	4.39	.751	.88	STA	2nd
BIN2	4.43	.684	.89	STA	1st

5.8.2 Factor Analysis (Impact of BIM)

This section follows the steps in Section 4.2.5.2 to conduct factor analysis and use the PCA extraction method and Varimax with Kaiser normalisation as the rotation method on the data generated in Nigeria. The analysis was conducted on the 17 identified impacts of BIM. As seen in Table 3.8, this study adopted .40 as the significant level, which was higher than the minimum required significant level for the sample size N=272. Thus, the retained component is significantly inclined. Table 3.8 also shows the guideline criteria adopted to conduct PCA on the 17 variables.

As explained in Section 4.8.2. Table 5.14 shows the CCM result for this study's BIM impact-related variables. The reason for showing this table is to check which rotation is adequate for the PCA. What to look out for in Table 5.14 CCM is to check any correlation between factors or components greater than .32 or less than -.32. From this table, there is no component greater than .32 or less than -.32. Therefore, orthogonal rotation can be adopted.

Table 5.14 Component correlation Matrix result

Component	1	2	3	4	5
1	1.000	.118	-.216	-.248	.153
2	.118	1.000	-.206	-.147	.130
3	-.216	-.206	1.000	.313	-.210
4	-.248	-.147	.313	1.000	-.191
5	.153	.130	-.210	-.191	1.000

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalisation.

Figure 5.11 clearly shows the five components with eigenvalues greater than 1.0, extracted with their variance explained by each component. Component 1 contributed 25.624%, Component 2 contributed 7.613%, Component 3 contributed 6.433%, Component 4 contributed 6.232%, and Component 5 contributed 6.157%. Altogether, the five components explained summed up 52.059% of the variability in the original 17 derivable BIM impacts in the Nigerian construction industry. Refer to Appendix 10 and Table 5.15 for the rotated clustering of the five components.

Total Variance Explained

Component	Initial Eigenvalues Total	% of Variance	Cumulative %	Extraction Sums of Squared Loadings Total	% of Variance	Cumulative %	Rotation Sums of Squared Loadings Total	% of Variance	Cumulative %
1	4.356	25.624	25.624	4.356	25.624	25.624	2.006	11.802	11.802
2	1.294	7.613	33.237	1.294	7.613	33.237	1.936	11.387	23.189
3	1.094	6.433	39.670	1.094	6.433	39.670	1.861	10.949	34.138
4	1.060	6.232	45.902	1.060	6.232	45.902	1.650	9.703	43.841
5	1.047	6.157	52.059	1.047	6.157	52.059	1.397	8.218	52.059
6	.981	5.769	57.829						
7	.860	5.060	62.888						
8	.825	4.850	67.738						
9	.729	4.287	72.025						
10	.710	4.174	76.199						
11	.679	3.997	80.195						
12	.663	3.902	84.097						
13	.624	3.671	87.769						
14	.607	3.573	91.341						
15	.572	3.364	94.705						
16	.461	2.710	97.415						
17	.439	2.585	100.000						

Extraction Method: Principal Component Analysis.

Figure 5.11 Rotated component matrix for BIM Impact

Table 5.15 BIM Impact components naming

Component naming	BIM derivable impact	Code	Factor Loading	Alpha α
Component 1				.635
Safety Management-related impact	Improve maintenance efficiency and safety of works.	BIN16	.747	
	Improve client brief drafting.	BIN17	.645	
	Decreased risk and cost incurred by contractor and subcontractors in a project.	BIN15	.527	
	Improved level of readiness for emergency occurrence (enhance safety)	BIN8	.449	
Component 2				.627
Design related impact	Eradicate design clashes amid professionals and contractors.	BIN7	.733	
	Enhance management of construction credentials in respect to early collaboration.	BIN9	.588	
	Eliminate/Reduce design errors	BIN12	.517	
	Enhance the virtual design of the existing building and its components	BIN13	.419	
Component 3				
	Improve construction scheduling/planning.	BIN14	.702	

Planning related impact	Improved day-to-day construction work progress and ease of tracking construction activities (Enhance Communication and Collaboration).	BIN6	.653	.648
	Enhance design self-confidence.	BIN10	.576	
Component 4				.687
Profit related impact	Improve ROI	BIN1	.771	
	Overall project cost reduction	BIN4	.565	
	Improved quality design and productivity.	BIN2	.463	
Component 5				.618
Construction Management-related impact	Enhance scheduling of work	BIN5	.751	
	Enhance project speed and save time	BIN3	.574	
	Ease of design discrepancy and omission detection (support construction and project management).	BIN11	.457	

Component 1: Safety Management-related impact

The four variables grouped in this component are the impacts BIM adoption and implementation have demonstrated, which are related to safety coordination and management. This can be linked from client briefing to the maintenance phase of the project. The variables are BIN16, BIN17, BIN15 and BIN8, with factor loadings of 0.747, 0.646, 0.527 and 0.449, respectively. They are also ranked 5^{th}, 2^{nd}, 13^{th}, and $17^{th,}$ respectively. The respondents strongly agree with the impacts having MIS of 4.27, 4.39, 4.20 and 4.13, respectively.

Component 2: Design-related impact

The design-related impact is the influence of the adoption and implementation of BIM in, for example, the design of architecture drawings and structural drawings, which these have enhanced the productivity of professionals saddled with every design-related aspect of the building. It also aids the transition of 2D drawings to 3D designs. Practically, it enables the professionals to eradicate design clashes, leading to proper management of construction documents due to early collaboration support and thus reducing design errors. Three variables were clustered under this component: BIN7, BIN9 and BIN12, ranked 7^{th}, 9^{th}, and $6^{th,}$ respectively, with MIS of 4.24, 4.26 and 4.26, respectively.

Component 3: Planning-related impact

Planning-related impacts are the on-site activities that need to be done before or during the allocation of daily or weekly tasks, such as day-to-day construction scheduling or planning. The implementation of BIM helps to facilitate this process. Based on this study's findings and the PCA result, three variables were grouped under this component: Improve Construction Scheduling/Planning, Improve Day-To-Day Construction Work Progress and Ease of Tracking of Construction Activities, and Enhance Design Self-Confidence.

Component 4: Profit-related impact

In construction, profit is a monetary gain, specifically the difference between what is gained and what is spent during building production. These can be calculated as: “Total Revenue - Total Expenses = Profit”. The adoption of BIM in building production has enabled the contractor and client to gain optimal profit compared to traditional building production methods. The variables identified are Improved ROI, Overall Project Cost Reduction, and Improved Quality Design and Productivity.

Component 5: Construction Management related impact

The management of day-to-day activities in every construction project cannot be neglected. It is the most crucial aspect of building production. BIM implementation has also significantly impacted the management of daily construction tasks. Based on the PCA result and the opinion of the Nigerian built environment professionals, three variables were grouped in this component: Enhance Scheduling of Work, Enhance Project Speed and Save Time and Ease of Design Discrepancy and Omission Detection. They have very significant MIS: 4.20, 4.21 and 4.20, respectively.

CHAPTER SIX: COMPARATIVE ANALYSIS OF BIM TECHNOLOGY APPLICATION IN BUILDING CONSTRUCTION AND MAINTENANCE MANAGEMENT IN NIGERIA AND SOUTH AFRICA

6.1 INTRODUCTION

This chapter compares the analysed results from Nigeria and South Africa to determine if there is a substantial difference from the viewpoint of the sampled professionals in each country.

6.2 DEMOGRAPHIC INFORMATION

Figure 6.1 presents the comprehensive statistical descriptive analysis of the respondent based on a percentage comparison of the demography information computation from both countries.

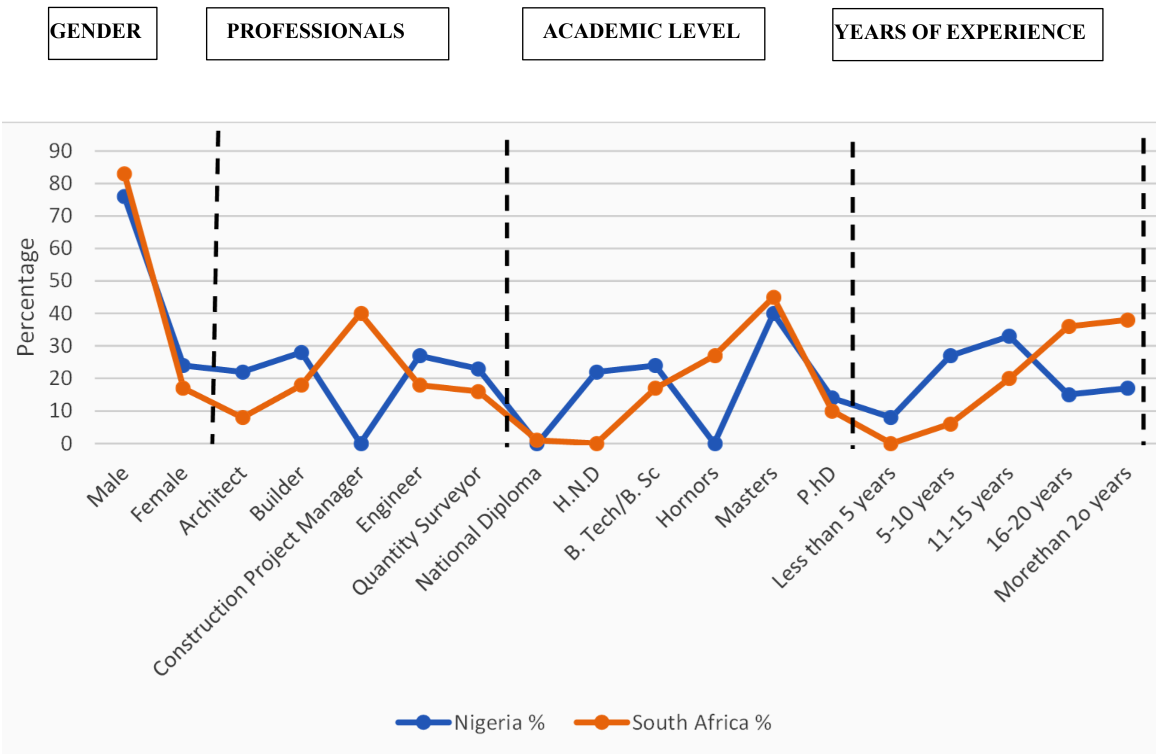


Figure 6.1 Demographic information comparison based on percentage

6.3 LEVEL OF INVOLVEMENT IN BUILDING LIFECYCLE

As shown in Figure 6.2, three crucial stages of the building lifecycle were presented with the comparison of data from Nigeria and South Africa based on the respondent's involvement, which was ranked on a 5-point Likert scale. The professionals' ratings on each stage were calculated based on a percentage and thereafter plotted, as seen in Figure 6.2. Based on this result, the following can be noted: at the design stage, there was no significant rating among the professionals from both countries, as the percentage difference ranged between 2% and 4% between each professional group. When comparing South African and Nigerian builders and engineers at the construction stage, the differences ranged from 3% (for engineers) to 5%. (builders). This implies that Nigerian builders and engineers are more focused on the construction stage than South Africa. However, South Africa has a construction project manager who, in this study, had more input in the construction stage than other professionals in South Africa. Thus, it can be said that construction project managers in South Africa are more committed to overseeing building construction. However, Figure 6.2 also shows that South African architects and quantity surveyors are more involved in the construction stage than Nigerian architects and quantity surveyors; the percentage difference was 6% and 5%, respectively.

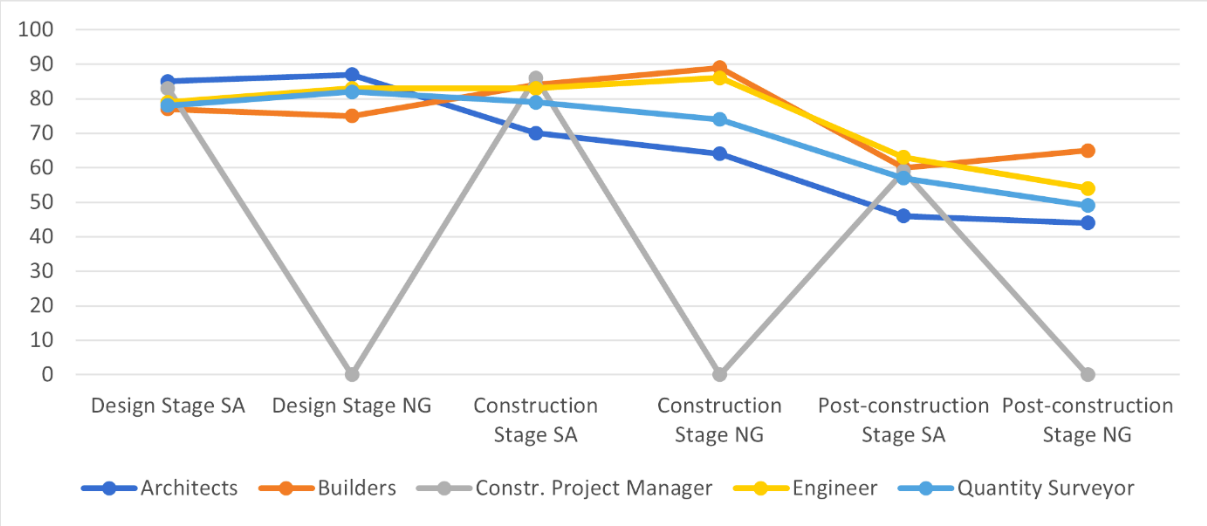


Figure 6.2 Level of involvement in the building lifecycle

6.4 BIM AWARENESS AND USAGE OF BIM TOOLS

From the data generated among the SACPMPC based on BIM awareness levels, it was recorded that 96.19% of the professionals who participated in the survey were fully aware of BIM use in the construction industry. At the same time, the data collected from Nigerian-built environment professionals indicated that 97.49% of the respondents were fully aware of BIM. These findings show that in both countries, registered professionals were more aware of its use in the construction industry.

From the results presented in Table 4.3 (South African result) and Table 5.3 (Nigerian result), seven of the BIM tools had received high usage levels among professionals in both countries. Although the mean weights were slightly different and the ranking was also the same except for “Revit and Sketchup” which were both ranked third and fourth in both countries, the results presented in Table 6.1 showed that out of the 33 identified BIM tools, those seven tools had received high usage.

Table 6.1 BIM tool usage comparison

Ranking	South Africa /MIS		Nigeria /MIS	
1	Microsoft Project	4.01	AutoCAD	4.26
2	AutoCAD	3.86	Microsoft Project	4.03
3	Revit	3.43	Revit	3.77
4	SketchUp	3.33	SketchUp	3.76
5	Autodesk BIM 360	3.23	ArchiCAD	3.59
6.	ArchiCAD	3.23	Vectorworks Architect	3.19
7.	Vectorworks Architect	3.03	Autodesk BIM 360	3.18

6.5 COMPARISON OF THE BARRIERS HINDERING BIM APPLICATION

Thirty-three impediments particular to developing nations were identified by this study and evaluated by registered building professionals in South Africa and Nigeria. The top ten barriers from the survey results, which are shown in Appendice 5 and 7, were taken from the results for both countries and are shown in Table 6.2 for comparison. This result showed that only three of the top ten barriers were common to both countries. For BCSA 2: "Lack of familiarity with BIM capacity" was ranked 1st in South Africa and ranked 2nd in Nigeria. This implies that this barrier is critical to both countries. BCSA26: "Government's unwillingness to support BIM use" was also ranked 6th and 7th; in both countries, the variables have a high mean weight. This means that the government and policymakers are yet to enact laws that will enforce the use of BIM in the construction industry. BCN1: "Low computer skills among some of the professionals" was ranked as the most critical barrier facing Nigerian built environment professionals. In contrast, it was ranked 10th in South Africa. Notwithstanding the differences in the level of ranking of low computer skills in both countries, its high mean scores indicate how it has significantly affected the usage of BIM in the construction industry.

Table 6.2 BIM barriers comparison

Ranking	South Africa /MIS		Nigeria /MIS	
1	BCSA2	4.05	BCN1	4.07
2	BCSA25	4.03	BCN2	4.04
3	BCSA12	3.92	BCN33	3.86
4	BCSA23	3.85	BCN32	3.84
5	BCSA13	3.84	BCN4	3.84
6.	BCSA26	3.84	BCN13	3.81
7.	BCSA14	3.83	BCN26	3.81
8.	BCSA20	3.83	BCN9	3.79
9.	BCSA16	3.83	BCN19	3.79
10.	BCSA1	3.83	BCN28	3.78

6.6 BENEFITS OF BIM USE

This study identified thirteen benefits of BIM based on a thorough analysis of the literature. The built environment professionals in both South Africa and Nigeria were asked to rank these benefits based on their knowledge of the use of BIM. The outcome demonstrates that both countries strongly rated the benefits as high; however, in South Africa, one of the factors (BB12: "Improved Construction Safety") had a mean value that was less than 4.00. This might be due to the barrier that South Africa ranked first: "lack of familiarity with BIM capabilities" in the BIM barriers.

6.7 COMPARISON OF BIM IMPACT RESULTS

The survey participants were asked to rate the criticality level of each variable based on the 17 significant impacts of BIM identified in the literature review. From the result computed for both

South Africa and Nigeria, it could be seen that all the BIM impacts are highly rated. Moreover, the top five rated impacts in each country are presented in Table 6.3. From this table, it could be seen that BIM "Increase digital representation" was unanimously ranked first in both countries. While BIM "Improve Client Brief Drafting" was ranked second in Nigeria and ranked fifth in South Africa.

Table 6.3 BIM impact comparison

Ranking	South Africa /MIS		Nigeria /MIS	
1	BI2	4.36	BIN2	4.43
2	BI12	4.28	BIN17	4.39
3	BI11	4.27	BIN1	4.32
4	BI14	4.22	BIN10	4.28
5	BI17	4.22	BIN16	4.27

6.8 STRATEGIES TO PROMOTE BIM-T APPLICATION AMONG CONSTRUCTION PROFESSIONALS FOR SUSTAINABLE BUILDING PRODUCTION IN AFRICA

This research elicited information from the respondents engaged in this survey. The respondents were asked to suggest possible strategies to promote the application of BIM in the African construction industry. They did so with the knowledge of their country because the construction activities in African countries are similar.

This section of the survey questionnaire was open-ended and optional. Here, the respondents were free to type in their responses based on their willingness to do so. . However, the 272 and 101 valid participants who participated in the Nigeria and South Africa surveys, respectively were deemed fit to participate in this section. Moreover, 59 (22%) and 44 (44%) respondents from this section agreed to join from Nigeria and South Africa, respectively. A total of 103 participants who contributed to this objective suggested possible strategies deemed suitable to promote BIM application. Figure 6.1 shows the gender percentage distribution of the respondents in both countries.

Notwithstanding, a total of 144 suggestions were received, which were categorised under eight headings. These can be seen in Appendix 11. However, one of the categories (others) was deemed an invalid response and removed from the final categories. Thus, the 141 valid suggestions yielded seven categories, as seen in Figure 6.2. Appendix 11 shows the responses extracted.

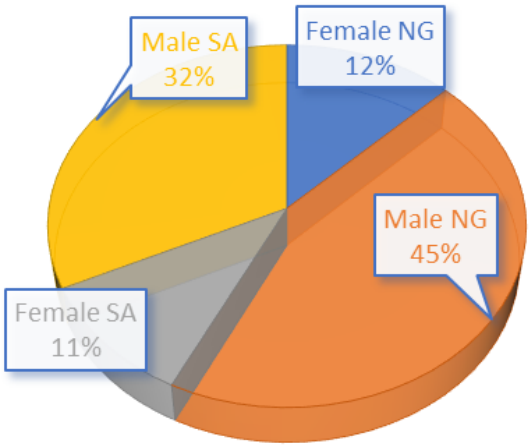


Figure 6.3 Gender percentage of respondents per country

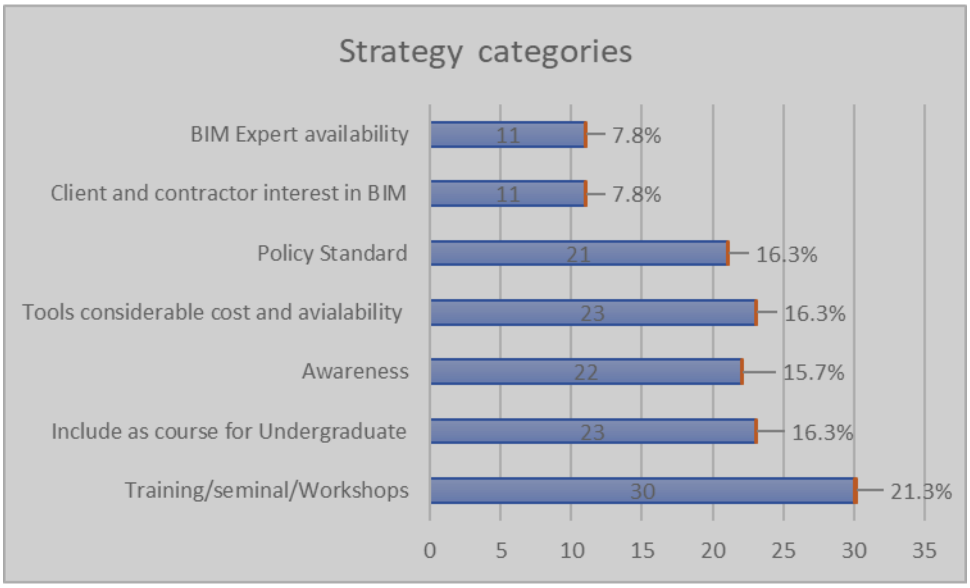


Figure 6.4 Categories of suggested strategies to promote BIM applications

6.8.1 Categorisation of the Suggested Strategies

The suggested responses were streamlined into seven good categories that fitted in with the respondent contributions. These categories are based on the close fitness of the suggestion to each group as extracted from the variables. The responses and the groupings can be found in Appendix 11., as performed on an Excel spreadsheet.

6.8.1.1 Training/Seminal/Workshops

From Figure 6.4, the respondents see training/seminars/workshops on BIM application and tools used by the professionals as a crucial strategy that could improve and promote the application of BIM technology across African countries. This received the highest number of responses (30) accounting for 21.3% of the responses.

6.8.1.2 Inclusion as a course for undergraduate

The inclusion of BIM as a course for built environment undergraduates in institutions was deemed very important. It will help to reduce the influx of graduates who are not well grounded in BIM knowledge and reduce the workload on BIM experts in training. In this category, 23 responses were received, forming accounting for 16.3% of the responses.

6.8.1.3Awareness

Even though almost all the respondents in this study agreed that they are familiar with BIM technology, they still see proper awareness of BIM's capacities, benefits and other factors as necessary strategies that could promote BIM application in the African construction industry.

6.8.1.4 Tools' considerable cost and availability

The availability of BIM tools at an affordable rate for the built environment professionals and all construction industry categories (small, medium and large) was deemed important by respondents. This strategy would accelerate their interest in adopting and applying BIM technology. Small and medium-sized businesses are most likely to benefit from it, while large corporations may be able to afford it at a high cost.

6.8.1.5 Policy Standard

In this regard, policy standards are the laws and modes of conduct put in place by the government, building code, policymakers and professional bodies. The respondents suggested that such measures should be in place to support BIM adoption and application, as is done in developed countries where BIM is mandatory for construction.

6.8.1.6 Client and contractor interest in BIM

Clients (private/public) and contractors are expected to advocate for the adoption and application of BIM in their projects. Based on this, the burdens fall on the professionals the clients meet first for briefing before going deep into the project. Such professionals must be well-equipped with BIM knowledge to advise the client on its benefits. This will then increase BIM adoption and application throughout the project lifecycle.

6.8.1.7 BIM expert availability

Lastly, under the categories, they suggested that the availability of BIM experts within the country would accelerate BIM adoption and its application in building production. More BIM experts among the built environment professionals will drive the firms or contractors into incorporate BIM in their projects.

6.8.2 Strategies that can promote BIM-T application

Tables 6.4 and 6.5 show the strategies that stand out in both countries that could be implemented, as suggested by the professionals. A check on both tables shows that some variables are the same in both countries. Therefore, high priority needed to be given to those variables, as it is a priority to promote the application of BIM in Africa.

Table 6.4 BIM promotion strategies (South Africa)

Strategies to promote BIM-T application among construction professionals for sustainable construction in South Africa.	
S/N	Suggested strategies
1.	SACPCMP should incorporate regular seminars and training on BIM use and capability throughout the building project's lifecycle for their members
2.	Increase BIM-T application awareness among built environment professionals through practical workshops and encourage more publications on BIM state-of-art
3.	Make tools and software affordable
4.	Major training drive to support BIM Managers on new development
5.	BIM should be added as a course in Institutions
6.	Government to design and implement policies that promote BIM-T as a standard framework for construction and project life cycle management
7.	Incentive approach on consulting professionals that uses BIM to enable in-depth sharing of Knowledge to beginners
8.	Clients should buy into the system of using BIM
9.	Adequate sensitisation of developers and government on the impact of adopting BIM-T and how it will benefit their projects.

Table 6.5 BIM promotion strategies (Nigeria)

Strategies to promote BIM-T application among construction professionals for sustainable construction in Nigeria	
S/N	Suggested strategies
1.	Increase BIM-T application awareness among built environment professionals through practical workshops and encourage more publications on BIM state-of-art
2.	Government or Professional bodies subsidise the tools and software yearly plan.
3.	Seminars and workshops on BIM should be regularly conducted in the country for the built environment professionals
4.	Integration of BIM-T as a course in the University curriculum
5.	Enforcement of the use of BIM by the Government, Professional bodies (NIA, NIOB, NIQS etc.) and Regulatory bodies (CORBON, COREN, ARCON etc.
6.	Inclusion of BIM documents as construction documents, such as Buildability and maintainability documents etc.
7.	Inclusion of client involvement for successful adoption of BIM
8.	Adequate training and education on BIM-T application for Construction professionals
9.	Making BIM-T tools accessible for professionals at little or no cost and adequate training should follow

CHAPTER SEVEN: CONCLUSIONS AND RECOMMENDATIONS

7.2 INTRODUCTION

This chapter summarises the study questions, findings and results, conclusions on the findings, contributions to knowledge, suggestions and future research directions.

7.2 SUMMARY OF KEY FINDINGS

This research purpose was achieved through the researched objectives that were relevant to the study's objectives, as explained in the research plan. The first objective is to assess the awareness and level of usage of BIM-T among construction and maintenance managers in South Africa and Nigeria. Objective two investigates barriers hindering BIM's successful application in South Africa’s and Nigeria’s built environment. The three objectives assess the benefits derived from BIM use in both countries. The fourth objective investigates the possible impact of successful BIM technology applications on construction and maintenance projects. While objective five identifies the strategies needed to promote BIM-T application among construction professionals for sustainable construction in developing countries.

7.2.1 Objective 1: BIM Awareness and Usage Level.

Regarding the level of awareness in both countries, the research has shown that the professionals are now aware of BIM technology, having 96.19% and 98.55% of respondents indicating they are aware of BIM in South Africa and Nigeria. This shows that previous research in this domain has contributed to BIM knowledge among professionals.

On the other hand, the level of BIM usage was checked by the rate at which the respondent used or applied the BIM tools in building production. Only 21.21% of the 33 BIM tools available in South Africa have been widely used among SACPCMP professionals. Microsoft Project and AutoCAD are at the top of the Bim tool list. This indicates a low level of usage of the tools in South Africa.

AutoCAD and Microsoft Project received a very significant usage level among Nigerian professionals; AutoCAD this is one of the significant tools used in the design stage and Microsoft Project is one of the significant tools used during construction stage of building production. Generally, the research found that only 21.21% of the 33 tools received a significant usage level in both South African and Nigerian construction industry. This also suggests that BIM tools are under-utilised in Nigeria. Therefore, both countries are still lacking in the use of BIM tools for building production.

7.2.2 Objective 2: BIM Barriers.

This study shows that lack of familiarity with BIM capacity, cost of BIM experts and time required for training are most critical among the 33 barriers peculiar to developing countries, while others are rated moderately critical. However, six barriers are not synonymous with the South African construction industry (BCSA7, BCSA8, BCSA14, BCSA18 and BCSA26). While for the Nigerian construction industry, two barriers were also deemed very critical: low computer skills among some construction professionals and lack of familiarity with BIM capacity. However, others are also rated critical. Moreover, the inferential analysis shows that BCN11 and BCN23 are not synonymous with the Nigerian construction industry.

7.2.3 Objective 3: Benefits of BIM application

In this research, 13 benefits were identified. From the perspective of South African professionals, 12 were seen as very important, while BB12 (improve construction safety) was seen as necessary. Although the professionals had a significant difference in the rating level of BB3, it was still rated as very important. The result from the Nigerian construction industry reveals that all 13 benefits were rated as very important, having strong M.I.S. From the perspective of the Nigerian professionals, the analysis shows a slight difference in the node weight of BB1 based on the professional rating. Nonetheless, it has a solid M.I.S.

7.2.4 Objective 4: Impact of Successful BIM Applications

Regarding the possible impact of successful BIM technology applications on the building production lifecycle as perceived from the perspectives of both South African and Nigerian professionals, the findings of this study confirmed that all of the variables identified positively impacted the building production process in the construction industry. This indicates that BIM adoption and use influenced design, planning, and overall construction management, allowing for appropriate profit realisation.

7.2.5 Objective 5: Strategies to Promote BIM-T Application.

Regarding the strategies needed to promote the BIM-T application in Africa, this study has shown that professionals are more concerned with its wide application. Their suggestions spread from the expected root of accruing the foundational knowledge (academic institution) of the technology down to the policymakers (government), the professionals (architects, builder, construction managers, engineers, quantity surveyors), and professional governing bodies as suggested across the two focused countries.

7.3 CONCLUSIONS

Based on the findings of this study, it is possible to conclude that there is an adequate awareness level of BIM among Nigerian and South African construction professionals. Still, much more effort has to be made to increase BIM understanding and use across the building production stages. This study established that there are still BIM-related barriers peculiar to both countries; these barriers could be responsible for their low adoption and application in some stages of building production. The contribution of built environment professionals and policymakers (government) in both countries will go a long way in limiting or eradicating these barriers and promoting their adoption and application. In addition, building and construction professionals also need to be willing to learn and adapt to new technologies to remain relevant and compete with professionals in the construction industry globally.

The results of the benefits derived from using BIM revealed significant agreement among the professionals on all of the identified impacts. It was noted that they are all very important. This means they already have an insight into the capabilities of BIM. Their ability to have sufficient working experience, engagement in building production and multiple uses of BIM tools across building design and construction stages aids their understanding of its importance. The result drawn from these research findings based on the impact of successful BIM application reveals that BIM has significantly improved building products through its contribution to performing tasks from building design to post-construction stages.

The findings on the strategies needed to promote BIM application in the construction industry advocated: the need for foundational knowledge in an educational institution on BIM tool use and its application throughout building production stages, With an emphasis on government and professional bodies' support in the actualisation of BIM technology in the countries and the readiness of the professionals to take charge of the innovative technology.

Finally, this study affirms that the extent to which BIM technology is used in building production in developing regions is still very low. There is a need to advocate sufficient training for the built environment professionals and to encourage educational institutions to incorporate BIM practice in their curricula. This will improve the utilisation of BIM tools and their application

7.4 RECOMMENDATIONS

The findings from this study lead to the following recommendations, which need to be in place to gain from the accruable benefits embedded with BIM adoption and usage throughout building production stages in developing countries.

A road map to guide effective BIM application must be developed for African countries. This will address the barriers and challenges encountered through and during its implementation at every stage of building production. Similarly, governments and policymakers must implement policies that will drive the adoption of BIM for public buildings, as is done in other countries where BIM application is substantially used in building projects. Also, professional bodies should embrace its adoption and assist in creating BIM training through seminars, conferences, and workshops. BIM training provides professionals with learning opportunities; consequently, they should be focused on enhancing their understanding of BIM principles and BIM applications.

Finally, these research findings have generated the following notable recommendations:

- Competencies in BIM tool usage should serve as a preliminary requirement for intending built environment professionals.

- BIM tools should be made available at a subsidised rate.
- The suggested strategies that will reduce the barriers hindering the application of BIM must be uncompromisingly and efficiently employed
- The identified BIM impact should be used to drive the application of BIM technology for building production.
- The benefits derived from adopting BIM should be used to motivate those who have yet to adopt it for building production and management in Africa.

7.4.1 Contribution to the Knowledge

This study has provided extensive in-depth knowledge and understanding of BIM's capability through its impact on and benefits to the construction industry. Also, its contribution to sustainable and fast delivery of buildings and a strategic way to promote its continual application in the African construction industry have made available the comprehensive barriers hindering BIM application in developing countries. It is known that most African professionals are now aware of BIM.

The practical contribution of this research's findings is that they will provide substantial support for the professional built environment bodies, government, educational institutes, and the current and aspirant built environment professionals in Africa by understanding BIM capability, capacity development requirements and the need to foster its adoption and application in building production. The findings of this research will also significantly benefit enable the development of a BIM road map guide for successful adoption and implementation of BIM in the African construction industry.

AREAS FOR FURTHER RESEARCH

The following areas require investigation:

- Scholars may investigate why BIM has not been integrated into academic built environment curricula across Africa.
- There is a need to create a supporting model to aid the implementation of BIM in the African construction industry.
- Researchers may create a framework combining building production phases from design through post-construction.
- A study should be conducted to ascertain the government's reluctance to embrace and enforce BIM adoption and application.
- Possible challenges that could be faced while implementing the strategies that would promote the application of BIM in Africa.

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APPENDIX

APPENDIX 1: BIM AWARENESS

CODING		BIM awareness
SOUTH AFRICA	NIGERIA	
BASA1	BAN1	The term BIM-T is more discussed or talk about these days
BASA2	BAN2	BIM-T stands to break information barrier in the future of building project
BASA3	BAN3	The government adopt BIM-T use for public sector building construction in South Africa /Nigeria
BASA4	BAN4	Private developer in South Africa /Nigeria have adopted BIM-T use
BASA5	BAN5	BIM-T is required to develop sustainable buildings
BASA6	BAN6	More BIM-T manufactural is needed to provide BIM-T object.
BASA7	BAN7	BIM-T expert in South Africa /Nigeria is very few
NOTE: BIM awareness South Africa (BAS)		

APPENDIX 2: BIM USAGE

CODING		BIM Uses by Building Facility Manager
SOUTH AFRICA	NIGERIA	
BUSA1	BUN1	It is Used to Facilitate the integration of building facility data into BIM databases and display the drawing of such components.
BUSA2	BUN2	It is used to plan maintenance routes (Predictive and Preventive) (U2)
BUSA3	BUN3	BIM automatically enables the building facility manager to perform Maintenance work orders through prompt scheduling. (U3)
BUSA4	BUN4	It is used to store and repairs information history on the facilities. (U4)
BUSA5	BUN5	It is used to ease maintenance work processes and effective asset management. (U5)
BUSA6	BUN6	BIM helps to locate building elements and components, allowing for better inspection and management. (U6)

APPENDIX 3: BIM USES POST-HOC COMPARISONS RESULT

Post-hoc comparisons (Multiple Comparisons)					
Tukey HSD					
Coding	Profession (I)	Profession (J)	Mean Dif. (I-J)	Std. Error	Sig.
BU1	Builder	Quantity Surveyor	.122	.335	.996
		Architect	-.694	.408	.437
		Engineer	.189	.335	.980
		Construction Project Manager	.222	.277	.929
	Quantity Surveyor	Builder	-.122	.335	.996
		Architect	-.817	.420	.302
		Engineer	.067	.350	1.000
		Construction Project Manager	.100	.295	.997
	Architect	Builder	.694	.408	.437
		Quantity Surveyor	.817	.420	.302
		Engineer	.883	.420	.228
		Construction Project Manager	.917	.375	.114
	Engineer	Builder	-.189	.335	.980
		Quantity Surveyor	-.067	.350	1.000
		Architect	-.883	.420	.228
		Construction Project Manager	.033	.295	1.000
	Construction Project Manager	Builder	-.222	.277	.929
		Quantity Surveyor	-.100	.295	.997
		Architect	-.917	.375	.114
		Engineer	-.033	.295	1.000
BU2	Builder	Quantity Surveyor	-.278	.338	.923
		Architect	-.319	.411	.937
		Engineer	.789	.338	.144
		Construction Project Manager	.194	.279	.957
	Quantity Surveyor	Builder	.278	.338	.923
		Architect	-.042	.423	1.000
		Engineer	1.067*	.353	.027
		Construction Project Manager	.472	.297	.509
	Architect	Builder	.319	.411	.937
		Quantity Surveyor	.042	.423	1.000
		Engineer	1.108	.423	.076
		Construction Project Manager	.514	.378	.655
	Engineer	Builder	-.789	.338	.144
		Quantity Surveyor	-1.067*	.353	.027
		Architect	-1.108	.423	.076
		Construction Project Manager	-.594	.297	.275
	Construction Project Manager	Builder	-.194	.279	.957
		Quantity Surveyor	-.472	.297	.509
		Architect	-.514	.378	.655
		Engineer	.594	.297	.275
BU3	Builder	Quantity Surveyor	-.067	.379	1.000
		Architect	-.125	.460	.999
		Engineer	.400	.379	.828
		Construction Project Manager	.417	.313	.672
	Quantity Surveyor	Builder	.067	.379	1.000
		Architect	-.058	.474	1.000
		Engineer	.467	.396	.763

		Construction Project Manager	.483	.333	.596
	Architect	Builder	.125	.460	.999
		Quantity Surveyor	.058	.474	1.000
		Engineer	.525	.474	.803
		Construction Project Manager	.542	.424	.705
	Engineer	Builder	-.400	.379	.828
		Quantity Surveyor	-.467	.396	.763
		Architect	-.525	.474	.803
		Construction Project Manager	.017	.333	1.000
	Construction Project Manager	Builder	-.417	.313	.672
		Quantity Surveyor	-.483	.333	.596
		Architect	-.542	.424	.705
		Engineer	-.017	.333	1.000
BU4	Builder	Quantity Surveyor	.333	.358	.884
		Architect	.083	.435	1.000
		Engineer	.667	.358	.344
		Construction Project Manager	.556	.295	.335
	Quantity Surveyor	Builder	-.333	.358	.884
		Architect	-.250	.448	.981
		Engineer	.333	.374	.899
		Construction Project Manager	.222	.314	.954
	Architect	Builder	-.083	.435	1.000
		Quantity Surveyor	.250	.448	.981
		Engineer	.583	.448	.690
		Construction Project Manager	.472	.400	.762
	Engineer	Builder	-.667	.358	.344
		Quantity Surveyor	-.333	.374	.899
		Architect	-.583	.448	.690
		Construction Project Manager	-.111	.314	.997
	Construction Project Manager	Builder	-.556	.295	.335
		Quantity Surveyor	-.222	.314	.954
		Architect	-.472	.400	.762
		Engineer	.111	.314	.997
BU5	Builder	Quantity Surveyor	.044	.388	1.000
		Architect	-.264	.471	.980
		Engineer	.444	.388	.781
		Construction Project Manager	.278	.320	.908
	Quantity Surveyor	Builder	-.044	.388	1.000
		Architect	-.308	.485	.969
		Engineer	.400	.405	.860
		Construction Project Manager	.233	.341	.959
	Architect	Builder	.264	.471	.980
		Quantity Surveyor	.308	.485	.969
		Engineer	.708	.485	.591
		Construction Project Manager	.542	.433	.722
	Engineer	Builder	-.444	.388	.781
		Quantity Surveyor	-.400	.405	.860
		Architect	-.708	.485	.591
		Construction Project Manager	-.167	.341	.988
	Construction Project Manager	Builder	-.278	.320	.908
		Quantity Surveyor	-.233	.341	.959
		Architect	-.542	.433	.722
		Engineer	.167	.341	.988
BU6	Builder	Quantity Surveyor	.144	.323	.992
		Architect	-.472	.393	.751
		Engineer	.144	.323	.992

		Construction Project Manager	.222	.267	.920
	Quantity Surveyor	Builder	-.144	.323	.992
		Architect	-.617	.405	.551
		Engineer	.000	.338	1.000
		Construction Project Manager	.078	.284	.999
	Architect	Builder	.472	.393	.751
		Quantity Surveyor	.617	.405	.551
		Engineer	.617	.405	.551
		Construction Project Manager	.694	.362	.314
	Engineer	Builder	-.144	.323	.992
		Quantity Surveyor	.000	.338	1.000
		Architect	-.617	.405	.551
		Construction Project Manager	.078	.284	.999
	Construction Project Manager	Builder	-.222	.267	.920
		Quantity Surveyor	-.078	.284	.999
		Architect	-.694	.362	.314
		Engineer	-.078	.284	.999

Appendix 4: PCA COMMUNALITIES

Communalities

	Initial	Extraction
1. Low computer skills among some construction professionals.	1.000	.683
2. Lack of familiarity with BIM capacity	1.000	.568
3. Habitual resistance to change from the traditional mode of design and build	1.000	.425
4. Poor awareness of BIM benefits	1.000	.474
5. Misunderstanding of BIM concept	1.000	.613
6. Lack of support from senior leaders of the construction industry from the traditional method of contracting to embrace the use of BIM technology	1.000	.603
7. Lack of well-develop practical strategies and standards	1.000	.648
8. Project risks caused by BIM	1.000	.544
9. Lack of support from owners and managers due to inadequate knowledge of BIM concepts	1.000	.550
10. Negative Attitude towards Working Collaborative.	1.000	.529
11. Lack of a Stable BIM tool Working environment.	1.000	.553
12. Lack of motivation to implement BIM in projects	1.000	.461
13. Inaccessibility to genuine BIM tools	1.000	.603
14. Absence of adequate quantifiable digital design information	1.000	.549
15. Difficulties in getting convenient time required for BIM training.	1.000	.553
16. Insufficient available BIM data	1.000	.481
17. Complex process of learning BIM technology	1.000	.608
18. Complexity in getting used to BIM technology and procedures	1.000	.535
19. Lack of BIM experts	1.000	.596
20. Reluctancy/lack of knowledge sharing by firms that have successfully implemented BIM	1.000	.481
21. Lack of organized BIM studying means	1.000	.556
22. BIM consulting market is confused	1.000	.544
23. High costs related to the BIM software, hardware and training	1.000	.528
24. Project planning costs increased	1.000	.561
25. Cost of BIM experts and time required for training	1.000	.572
26. Government not willing to support BIM use	1.000	.617
27. Missing insurance framework for BIM application	1.000	.455
29. The unclear sole ownership right of BIM tool data	1.000	.409
31. Absence of insurance applicable to BIM application	1.000	.519
32. Low knowledge about the BIM application principles and guidelines for certain project professionals.	1.000	.589
33. Absence of support from policymakers	1.000	.497

Extraction Method: Principal Component Analysis.

Appendix 5: ROTATED COMPONENT MATRIX FOR BIM APPLICATION BARRIER

Rotated Component Matrix[a]

Barrier codding	Component 1	2	3	4	5	6	7	8
BCSA29	.820							
BCSA30	.751							
BCSA28	.717							
BCSA27	.683							
BCSA31	.680							
BCSA33	.589							
BCSA32	.552							
BCSA4		.724						
BCSA2		.708						
BCSA5		.637						
BCSA6		.588						
BCSA3		.573						
BCSA9		.553						
BCSA7	X	X	X	X	X	X	X	X
BCSA15			.737					
BCSA16			.686					
BCSA13			.671					
BCSA17			.561					
BCSA10				.776				
BCSA21				.614				
BCSA22				.570				
BCSA20	X	X	X	X	X	X	X	X
BCSA8	X	X	X	X	X	X	X	X
BCSA19					.755			
BCSA23					.575			
BCSA18	X	X	X	X	X	X	X	X
BCSA24						.683		
BCSA25						.606		
BCSA26	X	X	X	X	X	X	X	X
BCSA14	X	X	X	X	X	X	X	X
BCSA1							.858	
BCSA11								.702
BCSA12								-.559

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 24 iterations.

Appendix 6: BIM TECHNOLOGY BENEFIT

CODING		**BIM-T Benefit**
SOUTH AFRICA	NIGERIA	
BB1	BB1	Increase digital representation
BB2	BB2	Enables understanding the project for best estimation of cost and time.
BB3	BB3	Allow Linking of the schedule to the 3D model in visualisation way
BB4	BB4	Speedup the rate of Quantity take-off
BB5	BB5	Allow feasibility of the construction schedule
BB6	BB6	control quality and speed up communication
BB7	BB7	Quick detection of drawings error
BB8	BB8	Efficient reuse of information in the database as it stores information centrally such as building types, materials used etc.
BB9	BB9	Promote Adaptation of standard building prototypes to site conditions
BB10	BB10	Improved company performance
BB11	BB11	Reduction in overall project cost
BB12	BB12	Improved construction safety
BB13	BB13	Effective construction sequencing, consistency and material procurement

APPENDIX 7: BIM IMPACT

CODING		**BIM-t Impact**
SOUTH AFRICA	NIGERIA	
BI1	BIN1	Improved ROI.
BI2	BIN2	Improved Quality Design and Productivity.
BI3	BIN3	Enhance project speed and save time (lessen time for routine data gathering and recording)
BI4	BIN4	Overall Project Cost Reduction
BI5	BIN5	Enhance Scheduling of Work (Facilitates the Planning of Resource and its Allocation)
BI6	BIN6	Improved day-to-day construction work progress and ease of tracking construction activities (Enhance Communication and Collaboration).
BI7	BIN7	Eradicate Design Clashes Amid Professionals and Contractors.
BI8	BIN8	Improved Level of Readiness for Emergency Occurrence (Enhance Safety)
BI9	BIN9	Enhance Management of Construction Credentials in Respect to Early Collaboration.
BI10	BIN10	Enhance Design Self-Confidence.
BI11	BIN11	Ease of Design Discrepancy and Omission Detection (Support Construction and Project Management).
BI12	BIN12	Eliminate/Reduce Design Errors.
BI13	BIN13	Enhance Proper Proactive Maintenance Scheduling and Improve the Management and Maintenance of Construction Project Infrastructures.
BI14	BIN14	Improve Construction Scheduling/Planning.
BI15	BIN15	Decreased Risk and Cost Incurred by Contractor and Subcontractors in a Project.
BI16	BIN16	Improve Efficiency and Safety of Works.
BI17	BIN17	Improve Client Brief Drafting.

APPENDIX 8: BIM USES POST-HOC COMPARISONS RESULT

Multiple Comparisons					
Tukey HSD					
Dependent Variable	(I) Profession	(J) Profession	Mean Difference (I-J)	Std. Error	Sig.
1. It is Used to Facilitate the integration of building facility data into BIM-T databases and display the drawing of such components.	Builder	Quantity Surveyor	-.106	.175	.931
		Architect	.121	.177	.902
		Engineer	.071	.169	.975
	Quantity Surveyor	Builder	.106	.175	.931
		Architect	.227	.184	.608
		Engineer	.177	.177	.751
	Architect	Builder	-.121	.177	.902
		Quantity Surveyor	-.227	.184	.608
		Engineer	-.050	.179	.992
	Engineer	Builder	-.071	.169	.975
		Quantity Surveyor	-.177	.177	.751
		Architect	.050	.179	.992
2. It is used to plan maintenance routes (Predictive and Preventive)	Builder	Quantity Surveyor	-.034	.151	.996
		Architect	.000	.153	1.000
		Engineer	-.205	.146	.499
	Quantity Surveyor	Builder	.034	.151	.996
		Architect	.034	.159	.997
		Engineer	-.171	.153	.681
	Architect	Builder	.000	.153	1.000
		Quantity Surveyor	-.034	.159	.997
		Engineer	-.204	.154	.548
	Engineer	Builder	.205	.146	.499
		Quantity Surveyor	.171	.153	.681
		Architect	.204	.154	.548
3. BIM-T enables the building facility manager to automatically perform Maintenance work orders through prompt scheduling.	Builder	Quantity Surveyor	-.055	.158	.985
		Architect	.010	.159	1.000
		Engineer	-.081	.152	.951
	Quantity Surveyor	Builder	.055	.158	.985
		Architect	.065	.166	.980
		Engineer	-.026	.160	.998
	Architect	Builder	-.010	.159	1.000
		Quantity Surveyor	-.065	.166	.980
		Engineer	-.091	.161	.943
	Engineer	Builder	.081	.152	.951
		Quantity Surveyor	.026	.160	.998
		Architect	.091	.161	.943
4. It is used to store inspections and repairs information history carried out on the facilities.	Builder	Quantity Surveyor	-.059	.149	.979
		Architect	.377	.151	.061
		Engineer	.104	.144	.889
	Quantity Surveyor	Builder	.059	.149	.979
		Architect	.436*	.157	.030
		Engineer	.163	.151	.704
	Architect	Builder	-.377	.151	.061
		Quantity Surveyor	-.436*	.157	.030
		Engineer	-.274	.152	.278
	Engineer	Builder	-.104	.144	.889
		Quantity Surveyor	-.163	.151	.704

		Architect	.274	.152	.278
5. It is used to ease maintenance work processes and effective asset management.	Builder	Quantity Surveyor	-.230	.171	.532
		Architect	.121	.172	.895
		Engineer	-.002	.165	1.000
	Quantity Surveyor	Builder	.230	.171	.532
		Architect	.352	.180	.208
		Engineer	.228	.173	.551
	Architect	Builder	-.121	.172	.895
		Quantity Surveyor	-.352	.180	.208
		Engineer	-.124	.174	.893
	Engineer	Builder	.002	.165	1.000
		Quantity Surveyor	-.228	.173	.551
		Architect	.124	.174	.893
6. BIM-T use help to facilitate locating of building elements and component, which allows for better inspection and management	Builder	Quantity Surveyor	.050	.153	.988
		Architect	-.161	.154	.724
		Engineer	-.152	.147	.731
	Quantity Surveyor	Builder	-.050	.153	.988
		Architect	-.211	.161	.556
		Engineer	-.202	.155	.558
	Architect	Builder	.161	.154	.724
		Quantity Surveyor	.211	.161	.556
		Engineer	.009	.156	1.000
	Engineer	Builder	.152	.147	.731
		Quantity Surveyor	.202	.155	.558
		Architect	-.009	.156	1.000

APPENDIX 9: ROTATED COMPONENT MATRIX FOR BIM BARRIER (NIGERIA)

Rotated Component Matrix[a]

	Component								
	1	2	3	4	5	6	7	8	9
18. Complexity in getting used to BIM technology and procedures	.678								
17. Complex process of learning BIM technology	.596								
16. Insufficient available BIM data	.570								
20. Reluctancy/lack of knowledge sharing by firms that have successfully implemented BIM	.568								
15. Difficulties in getting the convenient time required for BIM training.	.537								
10. Negative Attitude towards Working Collaborative.		.644							
13. Inaccessibility to genuine BIM tools		.636							
12. Lack of motivation to implement BIM in projects		.617							
14. Absence of adequate quantifiable digital design information		.602							
11. Lack of a Stable BIM tool Working environment.	X	X	X	X	x	x	x	x	x
21. Lack of organized BIM studying means			.598						
31. Absence of insurance applicable to BIM application			.588						
29. The unclear sole ownership right of BIM tool data			.507						
27. Missing insurance framework for BIM application			.505						
23. High costs related to the BIM software, hardware and training	x	x	x	X	x	x	x	x	x
6. Lack of support from senior leaders of the construction industry from the traditional method of contracting to embrace the use of BIM technology				.667					
7. Lack of well-develop practical strategies and standards				.660					
9. Lack of support from owners and managers due to inadequate knowledge of BIM concepts				.560					
3. Habitual resistance to change from the traditional mode of design and build				.506					
32. Low knowledge about the BIM application principles and guidelines for certain project professionals.					.716				
33. Absence of support from policymakers					.644				
1. Low computer skills among some construction professionals.						.771			
2. Lack of familiarity with BIM capacity						.727			
4. Poor awareness of BIM benefits						.504			
26. Government not willing to support BIM use							.682		
28. Lack of protocols in line with market demand							.521		
30. Contractual BIM environment							.477		
22. BIM consulting market is confused							.435		
5. Misunderstanding of the BIM concept								-.568	
24. Project planning costs increased								.538	
25. Cost of BIM experts and time required for training								.434	
19. Lack of BIM experts									.67
8. Project risks caused by BIM									-.53

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 14 iterations.

APPENDIX 10: BIM IMPACT PCA NIGERIA

Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
16. Improve Efficiency and Safety of Works.	.747				
17. Improve Client Brief Drafting.	.645				
15. Decreased Risk and Cost Incurred by Contractor and Subcontractors in a Project.	.527				
8. Improved Level of Readiness for Emergency Occurrence (Enhance Safety)	.449				
7. Eradicate Design Clashes Amid Professionals and Contractors.		.733			
9. Enhance Management of Construction Credentials in Respect to Early Collaboration.		.588			
12. Eliminate/Reduce Design Errors.		.517			
13. Ease of Design Discrepancy and Omission Detection (Support Construction and Project Management).		.419			
14. Improve Construction Scheduling/Planning.			.702		
6. Improved day-to-day construction work progress and ease of tracking construction activities (Enhance Communication and Collaboration).			.653		
10. Enhance Design Self-Confidence.			.576		
1. Improve ROI				.771	
4. Overall Project Cost Reduction				.565	
2. Improved Quality Design and Productivity.				.463	
5. Enhance Scheduling of Work (Facilitates the Planning of Resource and its Allocation)					.751
3. Enhance project speed and save time (lessen time for routine data gathering and recording)					.574
11. Ease of Design Discrepancy and Omission Detection (Support Construction and Project Management).					.457

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 6 iterations.

APPENDIX 11: OPEN-ENDED RESULT

Open-ended questionnaire result on strategies to promote BIM application (Nigeria and South Africa)

Kindly suggest strategies to promote BIM application i	Training / Seminal/ Workshops	Include as course for Undergraduat e	Awareness	Tools considerable cost and avialability	Policy standard	Client and contractor interest in BIM	BIM Expert availability	Others	Total Response Category Count
Total respondents who answered	30	23	22	23	21	11	11	3	144
% of respondents who answered	20.8%	16.0%	15.3%	16.0%	14.6%	7.6%	7.6%	2.1%	
conducting Seminars on BIM	1								
by conducting workshop training	1			1					
Have it as a course in Technical Colleges, Universities.		1							
By conducting Seminars and Trainings using the Professional	1								
increase awareness and make tools affordable			1	1					
Major training drive to support BIM Managers	1						1		
Increased awareness; product workshops and more publicati	1		1						
Have it as a course in Technical Colleges, TVETS, Universities. However the high		1		1					
Have it as a course in Technical Colleges, TVETS, Universities.		1							
The Questionnaire is way too long. Unfair for participants.😒								1	
conducting Seminars on BIM	1								
Make the tools affordable				1					
You must use policy standards					1				
Implementation of a compulsary BIM course at tertiary academic level		1							
Incentive approach on consulting professionals that uses BMI and promotion c		1					1		
There are better and improved systems now available								1	
Showcase examples of BIM-t implementation to promote benefits of technology, provide low co			1	1			1		
Make it affordable				1					
Government should encourage BIM use					1	1			
BIM enforcement by stakeholders		1			1				
Owner buy-in to the system		1	1		1				
Proper training	1						1		
Greater interaction on the use of BIM at all levels			1						
The use of any Information Modelling systems relies on the inputs from the team involved in the design. The South African Gove					1		1		
Clients to specify the use of BIM technology						1			
Make the tools affordable	1			1					
It must be affordable				1					
client should request for BIM						1			
Workshop on BIM application	1								
employer training before taking the job				1					
You must use policy standards					1				
Clients should encourage the use of BIM technology				1		1			
Making BIM-t tools accessible for professionals at little or no cost									
The tools should be affordable				1					
adequate training				1					
It needs to be taught to the construction industry professionals at Tertiary level		1					1		
You must use policy standards					1				
Make the tools affordable				1					
Get more users trained how to apply it efficiently. Beware that	1			1		1	1		
Make BIM more accessible to Built Environment professions, especially the "small people" who cannot afford t				1		1	1		
Mostly Developers and Government needs to be educated in th	1	1	1						
Train adequate and stop this digital nonsense ! if you wnat to save the planet from distruction								1	
more information sharing			1						
Get more users trained how to apply it efficiently	1								
By creating more awareness.			1						
Government, Professional bodies or BIM tool produces shoul	1			1					
Enforcement of the use of BIM by the Government, Professional bodies (NIA, NIOB, NIQS etc) and Regulatory bodies (CC					1				
Inclusion of BIM documents as construction documents such as Buildability and maintainability document etc.					1				
Intense awareness and education for undergraduates and practicing professio		1	1						
More awareness in high Institution.			1						
Integration of BIM-t course in university curriculum		1							
In-cooperation of BIM courses in Institutions curriculum.	1	1							
Inclusion of client involvement for successful adoption of BIM			1			1			
More training and awareness on the use of BIM-t	1		1						
Monthly awareness on the benefits of BIM and training on t	1	1	1						
BIM-t course should be taugh in university and colleges		1							
Integration of construction professionals and softwares for effective delivery of project							1		
Publicity			1						
Provide a conducive environment and more awareness about Bim within and out site the indus			1	1	1				
Enforce the use of BIM at all levels					1				
The Nigerian Government has should enforce BIM use		1			1				
Clients to specify the use of BIM technology for there project		1							
It training and tools should be affordable	1			1					
client should request the use of BIM for design						1			
Government should encourage the use of BIM for construction					1				
Enforcement of the use of BIM for construction					1				
use of BIM should be implemented					1				
Create means of understanding the application of BIM	1		1						
Make sure it is readily avialable				1					
Ehance BIM knowledge through seminars	1								
schools lecturers should be trained on BIM application	1	1							
More expert availability							1		
BIM training should be affordable				1					
University and polytecnic lecturers in built environment sho	1	1							
Making BIM-t tools accessible for professionals at little or no cost and adequate training should follow				1			1		
Proper arrangement of BIM adoption with contractors						1			
Legislature should pass the building could and allow the use of BIM					1				
Should be taken as a core study course for students in the built industry in the		1							
Adequate training and education for Construction professiona	1	1							
BIM road map should be created					1				
Model that support BIM intergration enforcement					1				
Enable avaialability of the tools at cheap rate				1					
increase awareness of BIM use			1						
By organising workshop for the professionals in the built envi	1								
Workshop on BIM should be organized regularly	1								
seminals on BIM application model	1								
Extensive training on it model creation	1								
Government support					1				
Client should pay for BIM services						1			
BIM-t application is awareness									
Use of tools training									
The only way to promote and add value to BIM-t application is	1	1	1		1				
traing on BIM	1								
Creation of BIM protocols					1				
More awareness on BIM-t and comfortable atmosphere to enhance it's workability especially in			1						
BIM technology needs to be adopted as a course in the Nigerian Universities. St		1							
There should be awareness and training of Personel for effect	1		1						
Publication of BIM-t and advertising it social media Page to enhance the application			1						
professionals should support BIM use						1			
More awareness			1						
Reduction in cost of softwares, trainings and availability of incentives				1					
student training from school		1							
BIM trainings	1								

APPENDIX 12: RESEARCH QUESTIONNAIRE

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Faculty of Engineering and the Built Environment
Durban University of Technology
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Durban, 4001

Appendix QUESTIONNAIRE: SOUTH AFRICAN LINK

QUESTIONNAIRE SURVEY ON THE LEVEL OF BIM TECHNOLOGY USAGE IN BUILDING CONSTRUCTION/ MAINTENANCE MANAGEMENT IN DEVELOPING REGIONS, CASE STUDY: SOUTH AFRICA AND NIGERIA.

I am James Olaonipekun, Toyin., a Master student in the Department of Construction Management and Quantity Surveying, Durban University of Technology, Steve Biko campus, Durban, South Africa. I am currently conducting research on "***An appraisal of BIM Technology Application in Building Construction and Maintenance Management in Developing Countries: The Case study of South Africa and Nigeria***"

The aim of this study is to investigate the extent to which BIM technology is put to use in building construction/building maintenance management in developing countries in order to promote BIM-t application among construction professionals for sustainable construction in the developing countries.
The Questionnaire seeks to:
1. assess the level of awareness and usage of BIM-t among construction/maintenance managers in South Africa and Nigeria.
2. investigate barriers to the successful adoption/application of BIM technology in South Africa and Nigeria built environment
3. assess the benefits of using BIM in the construction and maintenance of building facilities in South Africa and Nigeria.
4. investigate the possible impact of successful BIM technology applications on building construction and maintenance projects.
5. determine strategies to promote BIM-t application among construction professionals for sustainable construction in the developing countries.

You are kindly requested to complete the questionnaire. There are no names required in this survey. Participation is voluntary and you are free to withdraw at any time with no negative consequences to you. The questionnaire will take about 20 to 25 minutes to complete. The data collected will be treated anonymously and the findings of the survey will be used for the research purposes only. Please note that there are no risks, current or anticipated, to you as a participant in this research. Your co-operation will be greatly appreciated. For any queries or comments regarding the survey, please contact 22175967@dut4life.ac.za , Cell: +27632968452, or modupem@dut.ac.za cell: +27744870101.

Your completion of the survey will be understood to meet the requirements of informed consent according to the following:

"I have been invited to participate in the above-named study and have also been informed about my involvement in the research and what is required of me. I understand that:

- My participation in this research is voluntary;
- I may withdraw from the research at any time with no negative consequences for myself;
- This study has been described to me in a language that I understand;
- My answers will be kept confidential;
- I agree that my responses from the questionnaire can be used for the research

With full knowledge of all foregoing, I agree to participate in this study."

Thank you in anticipation of your positive response to this request.

Section A: Background information

This section of the questionnaire refers to background information. Please note that your response will remain anonymous. Your co-operation is appreciated.

1. Gender

☐ Male

☐ Female

2. Indicate your highest educational qualification completed?

☐ National Diploma (ND)
☐ Advance Diploma
☐ Honors
☐ B. Tech/B.Sc.
☐ Master's Degree
☐ Doctorate (PhD)
☐ Other (please specify) ……………..

3. Please indicate your profession?

☐ Builder

☐ Quantity Surveyor

☐ Architect

☐ Engineer

☐ Other (please specify)……………………..

4. Kindly indicate the years of professional experience?

☐ Less than 5 years
☐ 5 to 10 years
☐ 11 to 15 years
☐ 16 to 20 years
☐ More than 20 years

Section B: Level of awareness and usage of BIM-t among construction and maintenance managers in South Africa.

BIM is a digital representation of the physical and functional characteristics of a facility. It is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle; from earliest conception to demolition. A basic premise of BIM is the collaboration between different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM, to support and reflect the roles of such stakeholders.

This section of the questionnaire explores the current level of BIM-t awareness among built professionals in South Africa.

1. **Are you aware of Building Information Modelling Technology (BIM-t)?**

(a) Yes ( ) (b) No ( )

If yes, kindly indicate your level of awareness of BIM use on a 5-point Likert's scale,

1 = very low; 2 = low; 3= average; 4 = high; 5 = very high

1	2	3	4	5

2. **Which of the following construction phase have you apply BIM-t?**

- ☐ Conception and Design Phase
- ☐ Pre-construction Phase
- ☐ Procurement Phase
- ☐ Construction Phase
- ☐ Post-construction Phase
- ☐ None.

3. **How long have you been using BIM-t on projects?**

- ☐ N/A
- ☐ 0-2 years
- ☐ 2-5 years
- ☐ 5-10 years
- ☐ 11 ears and above

BIM AWARENESS
To what extent do you agree or disagree with the following statement regarding the awareness of BIM-t in South Africa? Use the following rating scale: 1=strongly disagree; 2= Agree; 3= neutral; 4= disagree; 5= strongly agree

S/N	BIM awareness	1	2	3	4	5
1.	The term BIM-t is more discussed or talk about these days					
2.	BIM-t stands to break information barrier in the future of building project					
3.	Government adopt BIM-t use for public sector building construction in South Africa					
4.	Private developers in South Africa have adopted BIM-t use					
5.	BIM-t is required to develop sustainable buildings					
6.	More BIM-t manufactural is needed to provide BIM-t object.					
7.	BIM-t expert in South Africa is very few					

level of BIM-t usage for construction/maintenance management.

Below are some BIM-t tools used for building production, kindly rate your level of usage of the listed tools. Using the following 5-point scale where: 1= Very low; 2= Low; 3= Average; 4= High; 5= Very High

S/N	BIM-t bases tools for Use for Building production	1	2	3	4	5
1.	Vectorworks Architect					
2.	ArchiCAD					
3.	Autodesk BIM 360					
4.	SketchUp					
5.	Revit					
6.	Navisworks					

7.	Revizto					
8.	Iris VR					
9.	BEXEL manager					
10.	Edificius					
11.	ArCADia BIM 11					
12.	VisualARQ					
13.	Midas Gen					
14.	Civil 3D					
15.	Buildertrend					
16.	Hevacomp					
17.	Sefaria					
18.	BIMx					
19.	AutoCAD					
20.	Bently Architecture					
21.	Computerized Maintenance Management System (CMMS)					
22.	Computer-Aided Facility Management (CAFM)					
23.	Integrated Workplace Management (IWMS)					
24.	Building Automation System (BAS)					
25.	Synchro Professional					
26.	Vico Control					
27.	Visual Application					
28.	D Profiler					
29.	Vico Takeoff Manager					
30.	QTO					
31.	Navisworks Manager					
32.	Microsoft Project					
33.	Navisworks simulate					
34.	**Other Please specify**					

STAGES INVOLVE IN BUILDING PRODUCTION

Please indicate the level of your involvement in the following stages of building life cycle. Use the following rating scale: 1= Never; 2= Rarely; 3= Sometimes; 4=Often; 5= Always

S/N	**Stages involved in Building Production**	**1**	**2**	**3**	**4**	**5**
1.	Design stage					
2.	Construction stage					

3.	Post construction stage (maintenance phase)					

USE OF BIM-t FOR MAINTENANCE

From your understanding of BIM-t, to what extent do you agree or disagree with the following statement regarding the usage of BIM-t for building facility maintenance in South Africa? Use the following rating scale: 1=strongly disagree; 2= Disagree; 3= neutral; 4= Agree; 5= strongly agree

S/N	Use of BIM-t for maintenance	1	2	3	4	5
.1	It is Use to Facilitate integration of building facility data into BIM-t databases and display the drawing of such component.					
2.	It is used to plan maintenance route (Predictive and Preventive)					
3.	BIM-t enables Building facility manager to automatically perform Maintenance workorder through prompt scheduling.					
4.	It is used to store inspections and repairs information history carried out on the facilities.					
5.	It used to easy maintenance work processes and effective asset management.					
6.	BIM-t use help to facilitate locating of building elements and component which allows for better inspection and management.					
7.	**Other Please specify**					

Section C: Barriers hindering the successful adoption/application of BIM technology in South Africa built environment.

To what extent do you agree that the following factors are the barriers hindering the successful adoption of BIM technology in South Africa built environment? Use the following rating scale: 1=strongly disagree; 2= disagree; 3= neutral; 4= agree; 5= strongly agree

S/N	BIM-t Barriers	1	2	3	4	5
1	Low computer skills among some construction professionals					
2	Lack of familiarity with BIM capacity					
3	Habitual resistance to change from the traditional mode of design and build					
4	Poor awareness of BIM benefits					
5	Misunderstanding of BIM concept					
6	Lack of support from senior leaders of the construction industry from the traditional method of contracting to embrace the use of BIM technology					
7	Lack of well-develop practical strategies and standards					
8	Project risks caused by BIM.					
9	Lack of support from owners and managers due to inadequate knowledge of BIM concepts					
10	Negative Attitude towards Working Collaborative.					
11	Lack of a Stable BIM tool Working environment.					
12	Lack of motivation to implement BIM in projects					

13	inaccessibility to genuine BIM tools					
14	Absence of adequate quantifiable digital design information					
15	Difficulties in getting convenient time required for BIM training.					
16	Insufficient available BIM data					
17	Complex process of learning BIM technology					
18	Complexity in getting used to BIM technology and procedures					
19	Lack of BIM experts					
20	Reluctancy/lack of knowledge sharing by firms that have successfully implemented BIM					
21	Lack of organized BIM studying means					
22	BIM consulting market is confused					
23	High costs related to the BIM software, hardware and training					
24	Project planning costs increased					
25	Cost of BIM experts and time required for training					
26	government not willing to support BIM use					
27	Missing insurance framework for BIM application					
28	Lack of protocols in line with market demand					
29	The unclear sole ownership right of BIM tool data					
30	Contractual BIM environment					
31	Absence of insurance applicable to BIM application					
32	Low knowledge about the harsh BIM application principles and guidelines for certain project professionals.					
33	Absence of support from policymakers					
34.	Kindly provide and rate additional barrier factors					

Section D: Benefits derived for using BIM-t in the construction and maintenance of building facilities in South Africa.

To what extent do you agree with the following as the benefit derive for using BIM-t in South Africa built environment. Use the following rating scale:
1=strongly disagree; 2= disagree; 3= neutral; 4= agree; 5= strongly agree

S/N	BIM-t Benefit	1	2	3	4	5
1.	Increase digital representation					
2.	Enables understanding the project for best estimation of cost and time.					
3.	Allow Linking of the schedule to the 3D model in visualization way					
4.	Speedup the rate of Quantity take-off					
5.	Allow feasibility of the construction schedule					
6.	control quality and speed up communication					
7.	Quick detection of drawings error					
8.	Efficient reuse of information in the database as it stores information centrally such as building types, materials used etc.					
9.	Promote Adaptation of standard building prototypes to site conditions					

10.	Improved company performance					
11.	Reduction in overall project cost					
12.	Improved construction safety					
13.	Effective construction sequencing, consistency and material procurement					
14.	**Other Please specify**					

Section E: Impact of successful BIM-t application on construction and Maintenance project.

Please indicate the impact of successful BIM-t application on construction project. Use the following rating scale: 1=strongly disagree; 2=disagree; 3=neutral; 4=agree; 5=strongly agree

S/N	BIM-t Impact	1	2	3	4	5
1.	Improved ROI.					
2.	Improved Quality Design and Productivity.					
3.	Enhance project speed and save time (lessen time for routine data gathering and recording)					
4.	Overall Project Cost Reduction					
5.	Enhance Scheduling of Work (Facilitates the Planning of Resource and its Allocation)					
6.	Improved day-to-day construction work progress and ease of tracking construction activities (Enhance Communication and Collaboration).					
7.	Eradicate Design Clashes Amid Professionals and Contractors.					
8.	Improved Level of Readiness for Emergency Occurrence (Enhance Safety)					
9.	Enhance Management of Construction Credentials in Respect to Early Collaboration.					
10.	Enhance Design Self-Confidence.					
11.	Ease of Design Discrepancy and Omission Detection (Support Construction and Project Management).					
12.	Eliminate/Reduce Design Errors.					
13.	Enhance Proper Proactive Maintenance Scheduling and Improve the Management and Maintenance of Construction Project Infrastructures.					
14.	Improve Construction Scheduling/Planning.					
15.	Decreased Risk and Cost Incurred by Contractor and Subcontractors in a Project.					
16.	Improve Efficiency and Safety of Works.					
17.	Improve Client Brief Drafting.					
18.	**Other; Specify**					

Section F: Determine strategies to promote BIM-t application among construction professionals for sustainable construction in the developing countries

In your own opinion kindly suggest strategies that can be used to promote BIM-t application among built professionals in your Country toward the sustainability of building construction and maintenance.

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………
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………………………………………………………………………………………………

Thank you for your time.

APPENDIX 13: DUT RESEARCH APPROVAL

DUT
INSTITUTIONAL RESEARCH ETHICS COMMITTEE

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
3rd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

30 March 2022

Mr J O Toyin
48 Botanic Court
Flat 6
Musgrave

Dear Mr Toyin

An appraisal of BIM Technology Application in Building Construction and Maintenance Management in Developing Countries: The Case Study of South African and Nigeria.
Ethics Clearance Number: 003/22

The Institutional Research Ethics Committee acknowledges receipt of your final data collection tool for review.

We are pleased to inform you that the data collection tool has been approved. Kindly ensure that participants used for the pilot study are not part of the main study.

In addition, the IREC acknowledges receipt of your gatekeeper permission letters.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC Standard Operating Procedures (SOP's).

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely,

Prof J K Adam
Chairperson: IREC

APPENDIX 14: SACPCMP GATEKEEPER APPROVAL

SACPCMP

The South African Council for the Project and Construction Management Professions

— CONSTRUCTING NEW PERSPECTIVES —

Address Unknown
4001

15 March 2022

Dear James Toyin

APPROVAL NOTICE FOR PERMISSION TO CONDUCT RESEARCH

The South African Council for the Project and Construction Management Professions (SACPCMP) has reviewed your request to conduct a research project involving the participation, in an online survey, of the Council's Registered Persons, in order to collect and utilize data related to your research project titled An appraisal of BIM Technology Application in Building Construction and Maintenance Management in Developing Countries: The Case Study of South Africa and Nigeria.

I am pleased to inform you that you have been granted approval to conduct the online survey on the Council's Registered Persons.

This approval notice is valid for two years as stipulated in Section 7.7 of the Application for Permission to Conduct Research Standard Operating Procedure.

SACPCMP's Stakeholder Relations and Communication Department will distribute the invitation to participate in the online survey, to the Registered Persons, upon receipt of this approval notice.

By signing the Applicant Declaration Form, as part of your application, you will undertake to use the data collected in a responsible manner and you have agreed to adhere to the conditions stipulated therein.

As part of the conditions of this approval you will be required to supply the SACPCMP with your final research dissertation or thesis for information purposes.

Kind Regards

SMC Kwenaite
Acting Manager: Education

Rigel Office Park, 446 Rigel Avenue, Erasmusrand, Pretoria, Gauteng Province, 0181
PO Box 6286 Halfway House, Midrand, 1685
Tel: 011 318 3402
www.sacpcmp.org.za

APPENDIX 15: NIQS LAGOS GATEKEEPER APPROVAL

NIGERIAN INSTITUTE OF QUANTITY SURVEYORS
LAGOS STATE CHAPTER
The professional construction cost managers.

5, Elegy Lane, Ojuelegba,
P. O. Box 1986,
Surulere,
Lagos.
niqslagos@yahoo.com, niqslagos@gmail.com
+234 (0) 701 364 9229, +234 (0) 803 360 3779
www.niqslagos.org

NIQS/LA/SEC/2020/2022

9th March, 2022.

Durban University of Technology,
Department of Construction management and Quantity Surveying
Steve Beko
4001

Attn: James Toyin

Dear Sir,

APPROVAL NOTICE FOR PERMISSION TO CONDUCT RESEARCH

We write in respect to your request seeking permission to carry out academic research on members of the Nigerian Institute of Quantity Surveyors, Lagos Chapter in order to collect and utilize data related to your research project.

I am pleased to inform you that you have been granted approval to conduct the research via an online survey on the Chapter's registered members.

This approval notice is valid for the duration of your research conduct only.

The NIQS Lagos Chapter will distribute the invitation to participate in the online survey to her registered members upon receipt of this approval notice.

By accepting this approval notice, as part of your application, you are obliged to use the data collected in a responsible manner and you have agreed to adhere to the conditions stipulated therein.

Finally, you are to supply the NIQS Lagos Chapter with your final research dissertation or thesis for information purposes.

Yours faithfully,

QS Foluso Ogunrinde MNIQS
GENERAL SECRETARY

QS Ayodele Alao FNIQS
CHAIRMAN

APPENDIX 16: NIOB LAGOS GATEKEEPER APPROVAL

Lagos State Chapter

THE NIGERIAN INSTITUTE OF BUILDING
(Statutorily backed by Act Cap 8, LFN, 2004)
LAGOS STATE CHAPTER
SECRETARIAT: BUILDERS' HOUSE,
CORBON Office: Eko Moore Towers,
Off Bode Thomas Street, Surulere, Lagos
Tel: 0806 717 3071, 0809 338 1614
e-mail: nioblagoschapter@gmail.com
info@nioblagos.org
www.nioblagos.org

CHAIRMAN
Bldr. Lucky Benome MNIOB

HON. SECRETARY
Bldr. Abiodun Ogundare MNIOB

NIOB/LA/SEC/ANCR/03-22/01

22nd March, 2022.

Durban University of Technology,

Department of Construction Management and Quantity Surveying,

Steve Beko

4001

Attn: Mr. James Toyin

APPROVAL NOTICE FOR PERMISSION TO CONDUCT RESEARCH

Sequel to your request seeking permission to carry out academic research on members of the Nigerian Institute of Building, Lagos State Chapter in order to collect and utilized data related to your research project.

This approval notice is valid for the duration of your research conduct ONLY.

The NIOB Lagos State Chapter will distribute the invitation to participate in the online survey to her registered members upon receipt of this approval notice.

By accepting this approval notice, as part of your application, you are obliged to use the data collected in a responsible driven manner and you have agreed to adhere to the conditions stipulated therein.

Finally, you are to supply the NIOB Lagos State Chapter with your final research dissertation or thesis for information purposes.

Lagos State Chapter

Yours faithfully

Bldr. Ogundare Abiodun, MNIOB
Honorary Secretary
09020323294

EXECUTIVES

IMM. PAST CHAIRMAN: Bldr. Sunday J. Wusu, FNIOB
VICE CHAIRMAN: Bldr. Thomas Adeoye, FNIOB
TREASURER: Bldr. Oluseson A. Phillips, MNIOB
FINANCIAL SEC.: Bldr. Olayinka Ojo, MNIOB
PUBLIC REL. OFFICER: Bldr. Godfrey C. Godfrey, MNIOB
ASS. HON. SECRETARY: Bldr. Aladelobo Adewale, FNIOB

Be wise, Build Right, Engage Professional Builders