ASSESSMENT OF THE EFFECT OF MODULAR CONSTRUCTION ON BUILDING PROJECT COST IN ABUJA.

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ABSTRACT

Modular construction is one form of prefabrication that exploits the advantages of factory assembly to a great extent, the idea being that the greater the degree of prefabrication, the greater the resultant benefit to the project. Various scholars have shown that modular construction is strongly linked to energy and cost effectiveness. In view of this, the study assessed the effect of modular construction on building project cost in Abuja. Data was collected from 50 construction sites in Abuja using a structured questionnaire with a response rate of 98.03. A purposive sampling technique was adopted for the study. The analysis of the data was carried out with the use of percentage, mean item score, and factor analysis. The study identified nine (9) drivers for the use of modular construction, of which the availability and accessibility of a skilled and experienced factory labour force (MIS = 4.38) is the most important. The study identified eight (8) barriers to the use of modular construction, of which two are financial barriers. (MIS = 4.54) is very important. The most important critical success factors for implementing modular integrated construction as a building construction method are an experienced workforce and technical capability (MIS = 4.52). The most significant effect of modular integrated construction practises on cost effectiveness is that they reduce the costs of design and development and/or maintenance of the project (MIS = 4.70). Factor analysis for critical success factors for implementing modular integrated construction as a building construction method revealed the KMO value is 0.594 and the Bartlett's test of sphericity is significant ($p > 0.05$). It can therefore be concluded that by knowing the current opportunities and challenges involved in the implementation of modular methods in the urban environment, practitioners would promote, plan, and implement modular methods better in the urban environment and achieve higher levels of modularization, which will then contribute to the productivity growth in the construction industry. Hence, appropriate measures such as wide adoption of prefab system considering their prospect of ensuring quality as a result of better supervision, professional bodies should hold seminars at intervals to educate and enlighten professionals on the requirements and advantages, the technique should be emphasised in continuous professional development (CPD) programmes were recommended to enhance the adoption of the modular construction method by professionals to ensure cost effectiveness in building construction projects.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Building construction can be an arduous process, rife with complications ranging from extreme weather conditions to work at excessive height and with limited access (Yang *et al.*, 2017). Indeed, the perils of the construction process are well known and documented and are accounted for with a number of sophisticated schemes designed to make the work smarter and safer, as well as to mitigate risk (Wuni *et al.,* 2019). For many years, advocates of using prefabricated building components have purported that bringing the construction process indoors in an industrialized manner is one of the most efficient and effective ways to improve building operations (Navaratnam *et al.*, 2019).

Prefabricating in a factory environment begins to move the construction process away from the field and shapes the process into one more akin to manufacturing. Work at the construction site then becomes a process of assembly rather than one of fabrication. Prefabrication is not a novel or revolutionary practice; rather, it permeates the building industry, and has for decades. The master builder previously manufactured doors, windows, and even bricks at the building site (Generalova *et al.*, 2016). Today, all of those components, and many more, are manufactured far away from the site and delivered as completed assemblies, ready to be installed. Modular construction is one form of prefabrication that exploits the advantages of factory assembly to a great extent, the idea being that the greater the degree of prefabrication, the greater resultant benefit to the project (Anthony *et al.,* 2013).

Literatures have demonstrated the impact of modular construction on productivity on major capital construction projects, the natural environment, human health and economy (Wei & Voellm, 2016; Alwan *et al.,* 2017; Dave *et al.,* 2014; Generalova *et al.*, 2016).

These studies have focused mainly on modular construction (Knaack *et al.,* 2012), benefits and challenges (Wuni and Shen, 2019; Wuni *et al.,* 2019), feasibility of modular construction (Velamati, 2012), application of modular construction in low and high-rise buildings (Lawson *et al.,* 2012), efficiency of time, cost and quality due to modular construction utilisation (Yoon *et al.,* 2015). However, in most developing countries little is known on the application of modular construction (Kibert, 2016; Lundholm *et al*., 2014).

Various scholars have shown that modular construction (Kibert, 2016; Musa *et al.,* 2014) is strongly linked to energy and cost effectiveness (Kibert, 2016; Wuni and Shen, 2019; Wuni *et al*., 2019) and withstanding disaster risk reduction (Wagemann, 2012).

Literature has shown benefits associated with modular construction such as improved project efficiency and effectiveness in terms of time, cost and quality, job creation (Yoon *et al.,* 2015), green cities (Volder and Dvorak, 2014), urban tourism (Kibert, 2016), ecological increase (Lundholm *et al.*, 2014) and climate change adaptation (Kamali and Hewage, 2016; Lee *et al.,* 2014; Yang *et al.,* 2017). Building construction projects in Nigeria are usually restricted to traditional methods and these are characterised by utilizing untested and uncertified materials and components. This results in unreasonably high-cost overruns. Nigerian construction industry has suffered many setbacks in terms of completion of projects at stipulated period and within the predetermined sum. Evidently, in the Nigerian construction industry, the application of modular construction is said to be significantly responsible for national development (Sholanke *et al.,* 2019).

1.2 Statement of the Research Problem

Modular building is well-known in the construction industry (Generalova *et al.,* 2016; Kennedy, 2016; Yoon *et al.,* 2015). The amount to which modular construction is employed is partially determined by the project team's resources, facilities, knowledge, and skills. These elements may be found deficient due to the limited utilisation of modular building in the Nigerian construction sector (Anthony *et al.,* 2013; Kibert, 2016). The primitive approach to building has limitations that make it difficult to achieve efficiency and long-term sustainability in construction projects. Furthermore, the strategy has caused a delay in meeting project goals, which has resulted in a delay in enhancing quality of life and national development. As a result, traditional building methods have failed to deliver infrastructure that is suitable for the current economic downturn (Harvey, 2013) and global environmental change (Jeong *et al.,* 2015).

Various investigations revealed the economic and energy dynamics that these techniques have on country development and living standards (Said *et al.,* 2014). However, little is known about the advantages of modular building, especially in Nigeria. Studies on the influence of modular building as a technique to achieve efficiency and sustainability of construction projects have been conducted elsewhere in the globe (Inyim *et al.,* 2014; Velamati, 2012; Lawson *et al.,* 2012). Given the importance of the building sector to the Nigerian economy, it is critical to resolve these issues. While modular building is improving in a number of nations, it seems to be underused in Nigeria. Building construction projects in Nigeria are usually restricted to traditional methods and these prefabricated houses that were delivered to be characterised by utilizing untested and uncertified materials, components and construction methods (Mbamali and Okotie, 2012). Majority of the construction projects in Nigeria experience time and cost overruns, which in turn lead to the abandonment of such projects (Kasimu and Usman, 2013). This study, therefore, seeks to investigate the drivers, barriers and effect of modular integrated construction on the cost effectiveness of building projects in Abuja.

1.3 Research Questions

i. What are the drivers of the use of Modular Integrated Construction Method?
ii. What are the barriers of the use of Modular Integrated Construction Method?
iii. What are the critical success factors for implementing modular Integrated construction as a Building Construction Method?
iv. What is the effect of modular integrated construction practice on building construction cost?

1.4 Aim and Objectives of the Study

1.4.1 Aim

The aim of this study is to assess the effect of modular construction on building project cost with a view to promote its usage for construction cost effectiveness.

1.4.2 Objectives of the study

Stemming from the research questions, the research intends to meet the following objectives:

i. To identify the barriers of the use of Modular Construction.
ii. To determine the drivers of the use of Modular Construction.
iii. To evaluate the critical success factors for implementing modular integrated construction as a building construction method; and
iv. To assess the effect of modular integrated construction practice on building construction cost.

1.5 Justification for the Study

In recent years, many studies have been drawn to Modular Integrated Constructions (MiC's) advantages and difficulties. For example, Kamali and Hewage (2016) examined the advantages of MiC as a sustainable building technique from the project life cycle viewpoint. MiC also saves time (Navaratnam *et al.*, 2019), reduces site activities (Jabar *et al.*, 2013), requires less site preparation (Pan & Hon 2018), and improves quality (Navaratnam *et al.*, 2019). Despite the advantages, there are many obstacles to MiC adoption across the world, including high initial costs, demand uncertainty, difficulties in achieving economies of scale, module transportation, coordination and planning difficulties, a lack of codes, and government support (Navaratnam *et al.*, 2019; Velamati 2012; Wuni *et al.*, 2019; Ferdous *et al.*, 2019; Hwang *et al.*, 2018).

The advantages and difficulties of MiC have usually been discussed in order to inform the construction industry about what they may expect when implementing MiC, which can vary depending on region, market condition, and formal government backing. From the perspective of Singapore, Rahim and Qureshi (2018) highlighted the benefits of MiC over prefabricated structures. Wuni and Shen (2020) conducted a comprehensive worldwide assessment of the literature to identify MiC's difficulties. Knowledge, attitudinal, financial, technological, aesthetic, industrial, procedural, and policy obstacles were divided into eight categories. Because of their diversity, our research revealed the hierarchical structure of MiC problems. Ferdous *et al.* (2019) discovered issues with MiC's technological advances in terms of designs and materials, such as a lack of design standards, a shortage of qualified employees, and transportation issues.

Zhang *et al.* (2014) studied the market in Mainland China and found variables that influence MiC growth. Similarly, Rahman (2014) focused on both the Mainland China and the UK markets, while Hwang *et al.* (2018) concentrated on the Singaporean market. Choi *et al.* (2019) identified transportation and site access as the major obstacles to MiC use in crowded metropolitan settings such as Hong Kong. Many research gaps were discovered after evaluating prior studies on the advantages and difficulties of MiC. To begin with, the bulk of prior research has mostly focused on difficulties. The advantages of MiC, on the other hand, need a thorough examination based on real-life case studies and consideration of the views of experts in the area. Second, despite widespread knowledge, a majority of experts in Nigeria do not use this building technique when designing inexpensive homes (Sholanke *et al.*, 2019).

By bridging these research gaps, our work will add to the corpus of knowledge. To begin, the research will examine the lessons gained from real case studies of MiC projects that have been completed in order to represent the true advantages of MiC implementation. The case studies will be chosen from among the MiC beneficiaries in Abuja. The second contribution is to take into account the hierarchical structure of MiC problems and to use a relative important index method to evaluate the relative importance of MiC challenges.

1.6 Scope of the Study

The study assessed utilization of Modular Integrated Construction as a building construction method in Nigeria with a view to ensure cost effectiveness in building construction projects in Nigeria using Abuja as a case study. This study focused on building construction firms that has made use of modular construction as a building construction method in past or present. This assessed the level awareness of modular construction as a building construction method. Also, the modular construction method benefits as a building construction method and the relative importance of modular integrated construction challenge was not out. Finally, critical success factors for implementing modular integrated construction as a building construction method was identified. For the purpose of this study, construction firms that engages in building and civil engineering works registered with Abuja Business Directory were considered.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview of Construction Industry in Nigeria

Nigeria's construction sector has recorded a phenomenal growth over the years due to the upsurge in demand for housing infrastructure required to support a growing population and the need to provide critical infrastructure to foster national and transnational economic investments. Consequently, this has vigorously opened up the construction market, especially real estate sector (Umar, 2015). Many policy changes in Nigeria's economic dynamics have tended to benefit the construction subsector the most. The industry is composite in nature with several players as stakeholders. It comprises indigenous and foreign firms operating at different scales in terms of size, manpower, equipment holding, financial capacity, and geographic boundaries. A large chunk of industry operators comprises foreign companies with close to 95% market holding, with a paltry 5% left for the small indigenous firms (Ismaila and Adegenga, 2018).

According to Sanusi (2009), Nigeria's construction industry drives most of the nation's economy and contributes about 5% increase in GDP growth. Other sectors of the national economy, such as health, education, and transportation heavily depend on the construction industry's products. The growth of economic and infrastructural development of Nigeria has been attributed to its construction industry (Ismaila and Adegenga, 2018). Construction industry in Nigeria contributes 3.23% to the nation's GDP, annually (Federal Office of Statistics, 2020). The industry also employs about 8 million people representing about 20% of Nigeria's workforce (National Bureau of Statistics, 2020). Globally, the construction industry is growing continuously. The sector is distinguished from other sectors as it is characterized by planning, design, construction, maintenance and repair and its operations transform various resources into constructed facilities (Isa *et al.*, 2013).

A major criticism of the Nigerian construction industry is the increasing rate of delays in project execution (Isa *et al.*, 2013). Generally, the performance of the nation's construction industry is a source of worry to the public and private sector clients, as well as other stakeholders. Quite a number of the nation's infrastructure projects have suffered several setbacks and some have been abandoned at various stages of completion owing to operational challenges, leading to difficulties in budgetary control (Isa *et al.*, 2013). Lack of local skilled labour, power shortage, unavailability of materials, and unethical practices are some of the common challenges ravaging the construction industry despite its performance (Isa *et al.*, 2013).

Nigeria's construction industry is also characterized by delays, time and cost overrun, project abandonment, dearth of skilled local labour, power shortage, material unavailability, corruption, unethical practices, and lack of execution apacity (Kolo and Ibrahim, 2010). The issue of delays in construction delivery has become a cankerworm, hence the need for increased awareness about its debilitating effects on construction productivity and performance. The problems of time and cost overruns are well known as the most common causes of delays in projects (Ismaila and Adegenga, 2018). New technologies such as prefabricated construction can be introduced into Nigeria's construction industry to reduce some of these challenges.

2.2 Industrialization and the Prefabricated Method of Construction

Through the years, industrialization in construction has resulted into the designing and manufacturing of more complicated building systems made up of a number of standardized and well-documented building elements. The system also enables project monitoring and experiential learning from the designing, manufacturing, and erection of the building system as a process for continuous improvement (Lessing, 2015). Thus, extensive and modernized knowledge of industrialized construction systems is not restricted to prefabrication and off-site manufacturing only, rather it is also inclusive of organized and controlled building elements notwithstanding whether these elements are produced in a factory or physically produced on site (Niclas and Jerker, 2017). Babic *et al.* (2010) opine the use of automation in industralization to facilitate the processes of construction delivery.

2.3 Modular Construction

Construction processes and the built environment have great impact on the environment, human well-being, as well as the overall economy. Sustainable construction in the environmental, social and economic dimensions are feasible through practical innovations and developments (Nahmans and Ikuma, 2012). Modular construction portrays the use of off-site pre-designed building units or parts that are conveyed to site as components of a building called modules (Steel Construction, 2017). Modular construction provides high quality products under controlled conditions, economies of scale through the use of prefabricated units, provides positive labour training implications by encouraging technical knowledge through the use of semi-skilled personnel significantly reduce building time and offer good economic value, which are some benefits over traditional construction methods (Boyd *et al.,* 2013). Modular construction can be used for either temporary or permanent building structures and are not subject to severe weather conditions unlike site-built structures. The modular construction concept can be applied to all types of building construction including offices, hotels, houses and retail stores (Akok and Prakask, 2017). Modular construction occurs in phases which are: predesign, design, develop, detail, order, fabricate, deliver and assembly (Smith, 2016).

2.3.1 Overview of Modular Integrated Construction

The Construction Industry Council (2018) defined MiC as an innovative construction method and technology whereby "freestanding integrated modules (completed with finishes, fixtures, and fittings) are manufactured in a prefabrication factory and then transported to site for installation in a building". Pan and Hon (2018) described MiC as the highest end of prefabrication involving the greatest integration of value-added factory-made prefinished modules. MiC constitutes the most complete form of OSC where 80 to 95% of a building can be completed in an off-site factory (Hwang *et al.,* 2018; Wuni *et al.,* 2019). Depending on the degree of modularization, Wuni *et al.* (2019), identified the four levels of MiC as components manufacture and subassembly (e.g. doors, light fittings), non-volumetric preassembly (e.g. panel systems, cladding panels), volumetric preassembly (e.g. plant rooms, bathroom pods) and complete modular buildings (e.g. modular restaurant, multi-residence housing). The three common types of MiC include reinforced concrete modules, steel frame modules, and hybrid modules.

Although MiC and the conventional construction approach have commonalities in the planning, design, statutory approval, site preparation, and development stages, significant differences between the two methods emerge beyond these phases. Wuni *et al.* (2019) described MiC as an innovation because it engenders significant changes to the way traditional projects are planned, procured, delivered, and managed. MiC have several disruptive effects on the construction industry. Unlike traditional projects where overlapping among construction phases can be tolerated, MiC lends itself to a fixed and unique supply chain involving a distinct sequence of modular design, procurement, engineering, manufacturing, transportation, storage, buffer, and on-site assembly (Wuni *et al.,* 2019; Wuni and Shen, 2019).

Multidisciplinary stakeholders dominate these distinct stages with their unique goals and value systems (Luo *et al.,* 2019), which increases the complexity of stakeholder management in MiC projects. Often, the modular components are made-to-order and designed to be used exclusively in a specific MiC project (Hsu *et al.,* 2018). Thus, scheduling requires that the quantity of each module produced precisely matches its optimum requirement for completion of the project and the inventory returns to zero on completion of the project (Hsu *et al.,* 2018; Wuni *et al.,* 2019). Overall, the unique business model of MiC has disruptive effect on construction cost engineering and quantification, defects rectification and treatments, and valuations of works (Wuni e*t al.,* 2019). The concomitant uncertainties associated with these changes are sources of scepticism and cynicism in the diffusion of MiC

Figure 2.1: Installation of Modular Home
Source: Wuni e*t al.* (2019)

2.4 Barriers to the Adoption of Modular Integrated Construction (MiC)

The adoption of MiC in the construction industry is a classic example of innovation diffusion in the sector (Wuni e*t al.,* 2019). The adoption of innovation is influenced by the perception of whether or not the innovation offers improved utility as against existing technologies and as such, a social process is required to reduce the uncertainties associated with the perceived utilities from the innovation. The diffusion of MiC into the construction sector is disruptive and demands significant changes to some entrenched practices. Given that the construction industry is slow to adopt innovative solutions (Ruparathna and Hewage, 2015), the diffusion of MiC is battling a hostile welcome amid complex host of barriers.

This research identified 120 barriers **(**actual and perceived) because as noted by Sepasgozar *et al.* (2011), the respondents in some studies did not have enough experience with MiC to comment on the actual barriers. However, the holistic argument in the current study provides legitimacy for the integration of all the barriers into a single conceptual framework. Based on an extended classification framework, the authors grouped the 120 barriers into attitudinal (10), industry (10), process (30), financial (15), technical (25), aesthetic (5), knowledge (15), and policy (10) barriers. The authors acknowledge and recognize that clustering the barriers into typologies is highly subjective and that there might be overlaps among the groupings. However, the grouping were informed by the previous clustering in empirical studies (Hamzeh *et al.,* 2017; Rahman, 2014). The clusters of barriers in discussed below

2.4.1 Attitudinal barriers

Attitude constitutes a behavioural pattern which makes a significant difference in innovation diffusion (Luo *et al.,* 2015). The settled way of thinking about the operations, relevance and business model of MiC has an influence on its diffusion into the construction sector (Luo *et al.,* 2015). The wider adoption of MiC is partly hindered by some uninformed perceptions of stakeholders. Luo *et al.* (2015) noted that some of the negative perceptions towards MiC are grounded on the historical failures of offsite construction techniques such as the post-war prefabricated construction strategies. Although there is improved perceptions towards MiC in the recent decade (Pan and Hon, 2018), the approach still suffers from the poor attitude of the construction industry towards innovation (Ku and Taiebat, 2011). 10 attitudinal barriers to the adoption of MiC. Particularly, some stakeholders still express scepticism about the actual benefits of MiC over the traditional construction approach (Lovell and Smith, 2010).

The negative mindset and low confidence in MiC may highlight the impact of the post-war prefabricated stigma on the wider acceptance and diffusion of MiC in the construction sector. The prevailing negative perceptions are driven by the limited MiC experience and knowledge of the respondents. This is evident because some studies identified that stakeholders are reluctant to adopt MiC because they believe rapid adoption will destroy architectural creativity (Rahman, 2014) and some claim modular homes have lower market values (Steinhardt and Manley, 2016). The former claim may be due to inexperience or limited knowledge of MiC because offsite architecture makes it possible for several designs to be created with same modules (Richard, 2006). Additionally, MiC offers more opportunity for architectural innovation since the same design details could generate highly diversified aesthetic options. The latter is also not justifiable because there is a growing market for modular homes in major cities around the world (Hwang *et al.*, 2018; Lee and Kim, 2017).

2.4.2 Knowledge barriers

Although the principles of MiC dates to the 12th century in line with the construction of Great Egyptian Pyramids in 2600 BCE, its current form is yet to be well-understood by many stakeholders and practitioners. Knowledge of MiC is and would be gained through education, training, and experience in its implementation (Zhang and Skitmore, 2012). The knowledge barriers reported in the literature are associated with the limited experience, skills, and understanding of MiC among the research participants, rendering some of the reported barriers speculative and "spurious". The limited understanding directly influences some of the attitudinal barriers (Zhang and Skitmore, 2012) highlighted above 15 knowledge barriers to the adoption of MiC.

The most critical knowledge barrier is the limited understanding of MiC business model (Zhang and Skitmore, 2012). The effective implementation of MiC requires high skilled manpower and powerful lifting equipment. Whiles these two are readily available in developed economies, they constitute significant inertia to the adoption of MiC in developing countries. Contractors, labourers and key players of the traditional construction approach require additional manufacturing skills to remain relevant in MiC projects (Wuni and Shen, 2019). Considering that MiC is still fledgling in some economies following its renaissance in the last 3 decades, previous generation of construction engineering and management graduates did not have the privilege of obtaining knowledge in MiC. For this reason, there are fewer trained and skilled operatives, contractors, and technicians with specialization in MiC. These further corroborate the role of education and training in creating well-informed attitudes towards the approach and its increased adoption. Studies have further reported that existing designers, manufacturers and suppliers do not have sufficient experience in the design, production and delivery of modular components (Zhang *et al.*, 2014; Zhang and Skitmore, 2012).

The limited knowledge further manifest into limited experience in design and installation of modular components (Luo *et al.,* 2015) and limited experience in MiC project inspection. Two other prominent knowledge barriers are difficulty in objectively ascertaining the value-added benefits of MiC and limited knowledge of the associated cost in the entire supply chain of MiC. Whiles the latter is less of a realistic barrier in recent times, the former remains a significant constraint to the adoption of MiC. Although studies have confirmed that MiC improves productivity, reduces waste, improves health and safety, reduces carbon emissions and reduces neighbourhood nuisance (Building and Construction Authority, 2019; Construction Industry Council, 2018), the monetary values of these are not often quantified and included in cost-benefit analysis. Thus, comparison between MiC and the traditional construction approach still draws on direct cost and benefits (Zhang and Skitmore, 2012). This accounts for the difficulty in ascertaining the value-added benefits of MiC. However, most of these barriers were reported in developing countries such as Malaysia, China, Nigeria, and Lebanon where the technology is not well-established. Nonetheless, improvement of these barriers is necessary for the wider uptake of MiC.

2.4.3 Technical barriers

The design and engineering of MiC projects are different from those of conventional construction projects. Particularly, MiC requires complex interfacing between modules, longer lead-in time (Zhang *et al.*, 2018) and highly restrictive tolerances (Zhang *et al.*, 2018). MiC is less tolerant to dimensional and geometric variabilities which are recipes for modular assembly errors, problematic rectification procedure and prohibitive costs of reworks (Shahtaheri *et al.*, 2017). As a result, stakeholders have expressed some level of resistance owing to the specialized tasks and technological requirements of MiC. 25 technical barriers to the adoption of MiC. Based on a frequency of occurrences in the literature, the most significant technical barriers include inflexible for design changes (TB7), insufficient capacity to fabricate enough modules (TB9), and unable to freeze design specification early to preassembly (TB23) (Zhang *et al.,* 2018). These barriers prevail in both developing and developed economies, suggesting that they (are perceived to) hinder the adoption of MiC. The technical barriers are associated with technical problems, risks and challenges inherent in MiC. Some other critical technical barriers are poor cooperation between multiple, inability to modify design during construction and constraints relating to conformity between different modules (Luo *et al.,* 2015). However, some of the technical barriers captured are either outdated or reported in developing countries where most of the respondents have little or no experience with MiC.

Given the progress of MiC in the last decade, (perceived) barriers such as lack of training and educational programmes on structural and architectural aspects (TB14), lack of technology and testing institute for modules (TB13), lack of standard components (TB12), lack of MiC research and development centres (TB10), and immature MiC technological system (TB4) are hardly verifiable and justifiable in developed economies such as the United States, United Kingdom, Hong Kong SAR, Canada, Singapore and Australia who have made significant advances in the technology. Particularly, MiC project engineering, operations, and management are now incorporated in many Universities CEM programme modules. Several MiC research laboratories are currently operations as MiC R & D centres.

Furthermore, the last decade witnessed improvement to some of the wicked technical challenges in the implementation of MiC. For instance, precise modular production technologies such as 3D fixturing and jig systems, laser cutting and robotic assembly are currently used to manage geometric variabilities in the modules (Shahtaheri *et al.,* 2017). There is also increasing use of laser scanning for inspecting and testing manufactured modules. This suggests that there are both perceived and actual technical barriers to the adoption of MiC in the literature. However, some barriers and problems such as inability to modify design during construction when needed (TB5), inflexibility for design changes (TB7), insufficient integrated design capacity (TB8) and complexity of error rectification (TB21) during on-site installation remain significant and pervasive. Improvement in structural design and engineering have produced in new generation of MiC projects which can accommodate strong wind loads and turbulence from earthquakes (Hong *et al.,* 2018). Thus, claims about the poor performance of MiC projects in times of earthquake can hardly be justified. Most of these perceived barriers are influenced by the limited knowledge of MiC and its progress (Gan *et al.*, 2019; Wuni *et al.*, 2019).

2.4.4 Financial barriers

Construction projects delivery is capital intensive and resources demanding. As such, the research clustered barriers associated with MiC project costs, risks, cash flows, and financial decisions into financial barriers. Shows 15 financial barriers to the adoption to the adoption of MiC. The most cited financial barrier is the higher (initial) capital cost associated with MiC. This paper recognizes that MiC requires significant capital (FB11) to establish modular factories, purchase moulds, secure yards, and to hire specialized workforce. However, there are some ambiguities associated withhow the cost barrier has been stated in the literature. For instance, it is stated as higher capital cost (Nadim and Goulding, 2011), increased initial cost (Nadim and Goulding, 2011) or high initial cost (Nadim & Goulding, 2011). These varying citations contribute to the poor understanding of the cost performance of MiC. Nonetheless, the exorbitant fixed overheads and sunk capital in factories (FB6) account for both the higher initial capital cost and the higher capital outlay for MiC (Luo *et al.*, 2015).

The higher cost translates into high bidding prices for contractors (FB8). In most countries, contractors are required to make early or upfront commitment in MiC projects (Hwang *et al.*, 2018), resulting in a significant disadvantage to small and medium scale enterprises who dominate the industries and yet, cannot afford such significant commitments. Furthermore, prevailing practices which favour lowest bid price rather than best values (FB2) render MiC less competitive (Lee and Kim, 2017). This is because the value-added benefits are hard to objectively ascertain and be incorporated into cost-benefit analysis (Lee and Kim, 2017). Another significant financial barrier is the difficulty in achieving economies of scale and quicker commensurate returns on the higher initial capital investment (FB4). The demand for MiC projects is cloudy and, in some cases, modular homes could take some time to be purchased. In such conditions, active capital of contractors and stakeholders are tied to MiC project for a very long time and act as disincentive to the wider implementation of MiC. There is also the difficulty in obtaining nancing for MiC projects (Mills, 2018). In New Zealand, banks provide significant advance payment to contractors throughout the building process using the traditional approach but in the case of MiC projects, banks provide funding only when the modules are assembled on site (Mills, 2018). In some countries, there are no innovative financing vehicles and sources for MiC. This inertia in obtaining finance for MiC projects act as a disincentive to the wider adoption of the technology.

The disruptive nature of MiC introduces significant changes to the payment terms and cash flows (FB1). Although the speedy construction associated with MiC translates into faster solvency and cash flow generation, it is still unclear regarding the contractual payment terms for MiC projects since the supply chain is fragmented and involves a complex web of stakeholders (Luo *et al.,* 2019; Wuni *et al.,* 2019). In countries with limited capacity to manufacture and supply the modules, cross-border transportation results in expensive logistics (FB7) for MiC projects (Pan and Hon, 2018). Even though MiC requires fewer workers on site, the use of skilled and specialized labour force results in payment of higher wages. Thus, the cost savings associated with the reduced labour sometimes becomes insignificant.

According to Wuni *et al.* (2019), MiC is associated with numerous risks and uncertainties (FB15) which could increase the cost of MiC projects (Lee and Kim, 2017) if not carefully identified, planned and managed. For instance, there is often the need to seek early professional advice on the suitable of the project design for MiC (Wuni and Shen, 2019). This generates additional project planning, design and procurement cost (FB14). Shahtaheri *et al.* (2017) reported that defects in MiC projects are expensive to rectify and reworks sometimes involves a repetition of the entire supply chain ranging from redesign through to remanufacturing and reassembly of modules on site. These constitute challenges with financial implications and serve as significant constraints to the adoption of MiC.

2.4.5 Process barriers

Compared to the conventional cast-in-situ construction approach, MiC is associated with a longer value and supply chain involving a complex network of stakeholders and processes. The supply chain of MiC involves planning, modular design, statutory approval, site preparation, and development, modular manufacturing, transportation, storage, buffer, and on-site assembly and installation. Thus, successful MiC implementation requires system integrators such as architects, designers, engineers, material suppliers, modular fabricators, developers, and contractors to beactively involved from initiation of the project through to the implementation of workflows in the design, construction, operations and maintenance stages (Zhai *et al.*, 2014). 30 process management barriers to the adoption of MiC. Majority of the process management barriers are intertwined with the supply chain and nature of the MiC business model.

At a simplified level, the construction of MiC projects involves design, engineering, production of modules, temporary factory storage, transportation to site, temporary site storage, and final assembly and installation (Wuni *et al.*, 2019). One significant process barrier is limited capacity of logistics to transport larger modules to job-site (PMB6). In most developing countries, the sizes and weights of the modules cannot be supported by the available trucks or nature of roads (Jiang *et al.,* 2017). The poor nature of transport systems in some countries result in significant damages to the modules during transportation to site (PMB2). The poor logistics services are recipes significant delays in the supply of modular components, which affects the schedule and cost of MiC (Wuni *et al.,* 2019; Wuni and Shen, 2019).

In cases where cross-border logistics services are sourced to supply modules, it results in increased transportation and logistical cost (PMB5). Transport regulations such as limitations to vertical heights of modules (PMB15) as well as size and load restrictions during transportation (PMB20) complicates the implementation of MiC. Additionally, given that modular plants in some countries are located in remote areas, transport restrictions on the size and load of modules generate logistics challenges in the implementation of MiC. When the modules are eventually transported to the job-site, some complications are still encountered which makes MiC unattractive in some circumstances.

For instance, there is the requirement of modular storage (PMB1) and demand for site specific logistics for protection of the modules (PMB3). In densely populated cities with scare developable lands, there will be serious problems with getting space for storage of the modules (Li *et al.,* 2018). In some developing countries, there are problems regarding hoisting capacity (PMB7) to support the on-site installation of the modules. This is because powerful cranes are not readily available or accessible to many contractors. Pan and Hon (2018) argued that the prevailing incomplete MiC supply chain (PMB8) in some countries constitutes the greatest threat to the wider adoption of MiC. In most cases, developers and clients are coerced to work with a fixed supply chain due to oligopoly of suppliers. Furthermore, the complex management process of MiC results from the requirement for increased communication among the complex web of stakeholders (Gan *et al.*, 2019) who have their unique goals and value systems within the MiC supply chain (Luo *et al.,* 2019).

MiC also requires extensive coordination of workflow, trades, resources, and stakeholders prior to and during the construction process (Hwang *et al.,* 2018). This unique requirement complicates the process of managing stakeholders in MiC projects. The prevailing lack of synergistic information platform (PMB14) constitute a significant challenge to collaborative working relationship and information sharing in MiC projects (Wuni *et al.,* 2019). However, the increasing use of real-time integrated building information modelling and radio frequency identification platforms allows for information sharing among project participants and real-time monitoring of the MiC supply chain progress (Li *et al.,* 2018). Moreover, supply chain disturbances and uncertainties such as weather disruptions, mechanical malfunction of cranes, and modular production plants operational inefficiencies may generate additional costs to the baseline budgets.

2.4.6 Policy barriers

Policies are the systems and machinery required to guide the implementation of an initiative towards achieving rational and measurable outcomes. The research identified barriers which are Process Management barriers (PMB)

PMB1. Storage of modular construction elements requirement

PMB2. Damage of modular components during transportation to the building site

PMB3. High demand for site specific and associated logistics for protection of modules

PMB4. Inability to supply modular products in a timely manner due to logistics limitation

PMB5. Increased transportation and logistics consideration e.g. cost

PMB6. Inefficient logistics to transport larger precast elements

PMB7. Lack of hoist capacity

PMB8. Lack of mature and tested supply chain

PMB9. Incapability of clients in providing good communication among stakeholders

PMB10. Lack of collaborative contracts

PMB11. Lack of long-term cooperation among MiC project teams

PMB12. Longer lead-in time during design stage

PMB13. Increased engineering complexity & difficulty to maintain

PMB14. Lack of synergetic information platform

PMB15. Limitation to vertical transportation

PMB16. Limited site space & restricted site layout

PMB17. Obliged to work with a fixed supply chain due to oligopoly of suppliers

PMB18. Poor integration of the entire supply chain

PMB19. Projects delay triggered by supply delay, shortage of raw materials and bad weather

PMB20. Size and load restriction on transportation

PMB21. Regular need for mobile crane to lift large load components

PMB22. Unsupportive decision made by designers

PMB23. Complicated management process and unavailability of best management practices

PMB24. Extensive coordination required prior to and during construction

PMB25. Training and upskilling of existing labour

PMB26. Complex procurement and contract system

PMB27. Conflict with traditional design and construction processes and practices

PMB28. Constraints on producing modular components locally due to limited materials

PMB29. Existing processes and tools are highly inconsistent with MiC requirements

PMB30. Unsuitable for smaller projects due to the need for bespoke design Process Management barriers (PMB)

2.4.7 Industry barriers

Historically, the construction industry is slow to adopt innovative business models and solutions (Gan *et al.*, 2019). The thinking and ideological orientation of the fragmented construction sector generate some barriers to the adoption of MiC. The paper recognizes the many overlaps and interrelationships between the attitudinal, knowledge and the industry barriers. Ten industry barriers to the adoption of MiC. One of the most cited industry barriers is the fragmentation of the construction sector (IB4) (Gan *et al.*, 2019). The sector is fragmented at both the industry and project level. For the latter, the prevailing lack of integration project processes or entities is inconsistent with the co-creation business model of MiC. At the industry level, there are so many firms or enterprises of varying sizes and several project types. Thus, it is obscure to diffuse the MiC technology into the fragmented environment. Two other most cited industry barriers to the adoption of MiC include conservative mindset of the industry towards conventional construction (IB1) and dominance of entrenched traditional construction practices (IB2). Change is difficult and unpleasant. It becomes more difficult if threatens the survival of companies and the jobs of people. Industry practitioners and stakeholders have stronger attachment to the traditional construction approach and will not adopt an innovative solution unless they are convinced that there is significant additional value or utility associated with the innovation. The conservative attitude is further strengthened because of the disruptive nature of MiC. The wider adoption of MiC will change many entrenched practices and will require new set of skills and techniques to remain relevant and competitive (Wuni and Shen, 2019). There is also fear of lost identity and role descriptors (IB3) (Gan *et al.,* 2019; Luo *et al.,* 2015).

This reality is critical because of the introduction of new project participants such as designers, manufacturers and assembly contractors. The traditional roles of several key project actors will be altered and taken over by other players if their skills are not upgraded. For instance, contractors may have to acquire manufacturing skills or fabricators will become the new contractors. Particularly, the implementation of MiC presents a threat to the traditional role of contractors who may become assemblers or "just concrete contractors". In addition, the implementation of MiC means the current culture of late design changes and modifications are slightly compromised. Thus, more rhetoric strategies are required to balance these conflicting issues in the implementation of MiC. It should be reiterated that the industry barriers are quite obscure to address as redress may take the form of significant structural changes in the industry. As such, the diffusion of MiC into the industry must be gradual but steady to reap the full benefits of the approach in the coming decades.

2.4.8 Aesthetic barriers

The heterogeneity of the built environment is a product of the different construction projects types from the disparate design and architectural specifications of clients. However, some less experienced stakeholders indicated that MiC is a recipe for monotonous design and structures (Zhai *et al.,* 2014; Zhang *et al.,* 2014). Five aesthetic barriers to the adoption of MiC. The research identified the most cited (perceived) aesthetic barriers as possible monotony of structure (AeB5), poor monotonous architecture and impaired outlook (AeB4), and concerns about the adaptability of MiC projects (AeB1). These perceptions are critical because clients enjoy multiple design options in the traditional construction approach. Thus, the perceived absence of these design options in MiC constitutes a source of skepticism towards the approach.

However, analysis of all the aesthetic barriers corroborates the argument (Sepasgozar *et al.*, 2011) that some of the studies engaged respondents with very little or no experience (and/or knowledge) of MiC. The reason been that during the last 3 decades, the renaissance and commitment to the implementation of MiC give birth to offsite architecture to cater for heterogeneous design requirement of MiC clients (Zhang *et al.*, 2014). From the concerns that MiC is not adaptable, flexible and customizable indicate that some of the aesthetic barriers are outdated and may reflect the inexperience and inadequate knowledge of some respondents. This is because MiC does not simply generate construction products but rather industrialized building system where same details generate highly individualized, diversified, adaptable, flexible and demountable houses (Zhang *et al.,* 2014). The whole MiC philosophy is grounded on the concept of modularity and modularization which increases adaptability and flexibility by allowing system integrators to mix, match and reconfigure modules obtained from various suppliers (Zhang *et al.,* 2014). Thus, citations of MiC as not flexible and adaptable probably reflects the inexperience of the respondents with MiC and does not truly represent any actual inflexibility (Zhang *et al.,* 2014).

2.7 Benefits of MiC

In this section we are going to demonstrate how MiC can enhance the construction sector of any given market and how various researchers were able to analyze and track the benefit of MiC and come up with facts and conclusions.

2.7.1 Time saving

MiC technology offers a benefit of time saving because it allows rapid construction. Simply, modules are brought to site then erected, and it overlaps the work on site with the work in the manufacturing facility (Molavi and Barral, 2016; Rahim and Qureshi, 2018). Furthermore, MiC can eliminate almost 80% of the construction site activities hence, eliminating a huge amount of delay due to resource management and weather problems (Navaratnam *et al.,* 2019). Using the manufacturing facilities provides a smooth flow of activities in a linear way for repetitive work, even better than performing linear activities on site. The use of machines and automation technologies also helps in enhancing this process and in decreasing the time. In addition, it helped solve the skilled labor shortage problem occurring in countries like Malaysia (Jabar *et al.,* 2013). Navaratnam, *et al.* (2019), believes that due to better delivery arrangements of materials to the manufacturing facilities and due to the eliminated delays of weather conditions and disruptions, the time saving achieved when using MiC can reach 40% compared to traditional/conventional construction methods, which means early operation of the project and accordingly a decrease in interest payments for capitals (Jabar *et al.,* 2013).

2.7.2 Risks, health and safety

MiC moves almost 90% of the construction activity to manufacturing facilities which eliminates a lot of risks like; weather condition, disruptions, equipment problems, labor low productivity and other sorts of risks that would make the project suffer more delay and incur extra costs (Rahim and Qureshi, 2018; Schoenborn, 2012). The reduction in on site activities makes the site tidier and decreases the occurrence of accidents among labors which enhances the construction industry and makes it safer (Rahim and Qureshi, 2018; Schoenborn, 2012). Kamali and Hewage (2016), mentioned that when using MiC reportable accidents was reduced by 80% compared to conventional methods. In addition, the reduction in usage of equipment, mainly in MiC we use lifting equipment only, the risk of damage to private properties due to the presence of huge amount of large equipment decreases.

2.7.3 Environmental, social and economic sustainability

Prefabrication or Off-site construction (OSC) helps in decreasing the wastage of material and provide cleaner (Kamali and Hewage, 2016). Navaratnam, *et al.* (2019) stated that OSC has great environmental positive impact from noise reduction and decrease in disruption by 30 to 50%. In addition, OSC buildings are known to promote recycling especially when using steel structure modules, Kamali and Hewage (2016) reported that 76% of researchers confirmed the ability of MiC system to reduce construction wastage. Marjaba and Chidiac (2016), stated that OSC, which ranges from prefabrication of cladding to prefabrication of complete modules, offers less wastage in material, reduction in environmental impacts compared to conventional method, and ability to build according to higher specification if needed. Furthermore, OSC allows the application of lean production principles which improves sustainability. In fact, OSC would result in wastage less than 5% Marjaba and Chidiac (2016), and it would also decrease the carbon emissions resulting from transportation due to the reduction of transportation required, particularly in MiC (Marjaba and Chidiac, 2016). In general, MiC provides positive impacts on the three aspects of sustainability; environmental, social and economic.

2.7.4 Quality enhancement

Quality enhancement is one of the most guaranteed benefits of MiC, the manufacturing facilities provide adequate fabrication Musa *et al. (*2014) for all components in a better work environment with more advanced production lines, machines and automation technologies. The precision available in factories reflects in higher quality, better efficiency and easier application of higher specifications or standard (Musa *et al.,* 2014). The application of quality control (QC), quality assurance (QA) and total quality management (TQM) in manufacturing facilities is much better Molavi and Barral (2016), and effective compared to its application on site, which paves the way to the application of lean production /Construction. The off-site production process allows close monitoring by multiple specialized persons and shall result in better quality for products (Kamali & Hewage (2016), demonstrated two further benefits for MiC, first, the workers will have better learning curves when working in factories compared to site activities because of small tasks assigned to each worker which promotes "work specialization". Second, all of the material will be away from severe or harsh weather conditions, thus, the final products will have high quality building finishes.

2.6 Effect of Modular Integrated Construction Practice on Cost effectiveness

In general, the benefits of MiC from the cost point of view can be concluded easily. First, time is money Kamali and Hewage (2016), so as project duration is reduced the time-dependent costs are reduced such as crane renting cost (Jabar *et al.*, 2013; Kamali and Hewage, 2016). Second, the site preparation and mobilization for MiC projects are much simpler, leading to a reduction in costs (Pan *et al.,* 2012). Third, the percentage of rework compared to the conventional methods would decrease to only 10 to 20% as a consequence of minimal on site activities, resulting in cost reduction for owners and less risk of budget overruns for contractors. Furthermore, during the bidding stage, a contractor will evaluate the risks of MiC to be lower than the traditional methods, as these methods include higher health and safety precautions (Schoenborn, 2012), bigger exposure for adverse weather conditions, bigger risk of poor workmanship from labors resulting in more rework and finally, risk for damage to property is much higher (Kamali and Hewage, 2016).

This will reduce the risk percentage the contractor is taking into account during bidding stage. In addition, it is standard procedure in projects that the contractor insures the project with various types of insurance policies as per the contract conditions. When using MiC, the feature of the project is different, it is much safer now which can lead to reduction in cost of insurance policies' premium. Furthermore, from the owner's perspective, the project shall not suffer from variation orders like the traditional ones, the MiC technique obliges all parties to a certain time after which no changes are allowed which leads to much lesser variation orders or no variation orders.

By numbers, Kamali and Hewage (2016) and Hong *et al.* (2018), stated that cost reduction in capitals when using modular construction can reach 10% while, Navaratnam, *et al.,* (2019) and Kamali and Hewage (2016) discussed the benefit of lower material prices due to bulk orders when using MiC. Kamali and Hewage (2016), mentioned that MiC reduces the labor cost by 25% compared with the traditional method. Wuni and shen (2019) identified 10 factors affecting the cost performance of modular projects which are reduces the waste of materials, reduces the cost of rework, helps achieve accuracy of the cost estimate, reduces the costs to design and develop and/or maintain the project , increases the Profit rate of project, reduces the cost of variation orders, reduces the overhead cost of the project, increases project cash flow, reduces the material and equipment costs, and reduces the cost of travel and expenses as well as cost to train.

2.7 Success Factors for Modular Integrated Construction Projects

Given the limited amount of published research on MiC projects, bespoke success factors can hardly be retrieved directly from the literature (Wuni and Shen 2019). However, there are some relevant studies on the success factors for other OSM techniques such as industrialized building systems (IBS), prefabricated prefinished volumetric construction (PPVC), modular construction, prefabrication, prework, and volumetric modular construction which are relevant to MiC projects (Hwang *et al.,* 2018). This is because MiC has many similarities with the modus operandi of these OSM techniques. Thus, the research conducted a comprehensive review of the relevant literature to identify the success factors which may be applicable to MiC projects.

Song *et al.* (2005) found that the prominent CSFs for pre work on industrial projects include realistic economic analysis, early commitment to the approach, availability of skilled management team, and availability of sound infrastructure network for transporting the modules to site. Tam *et al.* (2007) identified suitable procurement strategy and contracting to be a CSF for prefabricated construction projects. Blismas *et al.* (2005) summarized the 5 top CSFs for modular construction projects as robust design specification and early design freeze, effective supply chain management, early involvement of key participants, suitable procurement strategy, and relevant experience and knowledge of key players. Blismas and Wakefield (2009) conducted a questionnaire survey and identified that early commitment is a CSF for OSM projects.

Pan *et al*. (2012) conducted a questionnaire survey in the UK and found that robust engineering specification, design robustness and early design freeze constitute CSFs for industrialized housing projects. Choi *et al.* (2016) concluded that timely design freeze, long lead equipment specification, fabricator/ supplier involvement, and effective risk management are the four prominent CSFs for industrial modular construction projects. Li *et al.* (2018) conducted a questionnaire survey in China and found that the prominent CSFs for planning and control of prefabricated construction projects include involvement of key players at the earliest stages of the project, adequate knowledge and experience of key participants, effective communication and information sharing among project participants, efficient use of information and communication technology, and proper coordination between onsite and off-site trades. Even though a plethora of research have expounded on the CSFs for various OSM techniques, there is no specific empirical study on CSFs for MiC in the extant literature (Wuni and Shen 2019). Nonetheless, the comprehensive review of the literature provided a good framework and reference point to identify the CSFs which may be relevant to MiC projects. Table 2.1 is the summary of the potential success factors for MiC projects from the literature review.

Table 2.1 Summary of the potential success factors for MiC projects from the literature review.

Success factors	References
Robust drawing specification and early design freeze	Wuni and Shen (2019)
Adequate experience and knowledge of key players	Li *et al.* (2018); Wuni and Shen (2019)
Standardization and mass production	(Blismas *et al.* 2005)
Extensive project planning, scheduling and control	Lessing (2015); Li *et al.* (2018)
Good working collaboration, communication and information sharing	Pan *et al.* (2012); Choi *et al.* (2016)
Effective coordination of the supply chain segments	Blismas *et al.* (2005); Wuni and Shen (2019)
Fabricator experience and capabilities in modules design and production	Wuni and Shen (2019)
Suitable procurement strategy and contracting	Blismas *et al.* (2005); Tam *et al.* (2007)
Early advice from experts and consideration of MiC	Blismas and Wakefield (2009); Wuni and Shen (2019)
Experienced workforce and technical capability	Hwang *et al.* (2018)
Effective coordination of on-site and off-site trades	Li *et al.* (2018); Wuni and Shen (2019)
Alignment on MiC project drivers and modules architecture	Choi *et al.* (2016)
Availability of sound local transport infrastructure	Hwang *et al*. (2018); Wuni and Shen (2019)
Early completion and cost savings recognition	Choi *et al.* (2016); Wuni and Shen (2019)
Availability of skilled workforce, management and supervision team	Hwang *et al*. (2018); Wuni and Shen (2019)
Realistic economic analysis, early decision and definition of project scope	Song *et al.* (2005); Blismas and Wakefield (2009)
Availability and active involvement of key project team members from the earliest stage of the project	Pan *et al.* (2012); Wuni and Shen (2019)
Effective supply chain and execution risk management	Choi *et al.* (2016); Wuni and Shen (2019)
Support and early involvement of top management in supply chain decision-making)	Hwang *et al*. (2018); Wuni and Shen (2019)
Appreciation of key early decision and their implication between all parties involved	Blismas and Wakefield (2009); Wuni and Shen (2019)

Effective use of information and communication technology (e.g., BIM)	Li *et al*. (2018); Wuni and Shen (2019)
Effective coordination and management of stakeholders	Choi *et al.* (2016); Wuni and Shen (2019)
Module envelope limitations	Choi *et al.* (2016)
Early involvement of modules suppliers and fabricators	Choi *et al.* (2016); Wuni and Shen (2019)
Continuous improvement	Choi *et al.* (2019)
Owner delay avoidance	Choi *et al.* (2016)

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Introduction

This research work focused on utilization of Modular Integrated Construction as a building construction method in Nigeria with a view to promote its usage in building construction projects. This chapter outlines the research methodology that was adopted to ensure the reliability and proper understanding of this research. These include research design, research population, sampling frame, and sampling size, sampling techniques, method of data collection and method of data analysis. The detailed of explanation of each unit were given to aid understanding of the methodology for achieving the aim and objectives. as shown in Figure 3.1 below.

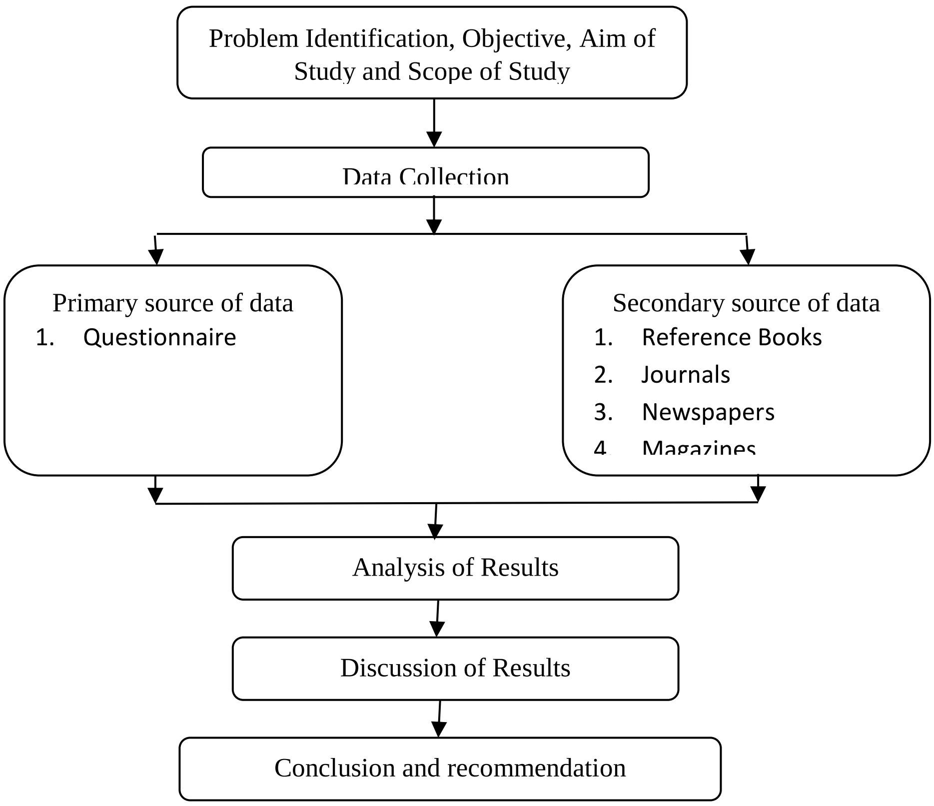

Figure 3.1: Flow Chart of Research Methodology as employed in the study.

3.2 Research Design

Research design is a plan and structure adopted to investigate and obtained solution to research questions, depending on the problems or questions addressed (Kumar, 2011). The selection of appropriate research design considered the time dimension, and control of the variables, and the degree of manifestation of the problems (Mustapha, 2012). Research design is the blueprint of research that deal with at least four problems; what questions to study; which data are relevant; what data to collect; and how to analyze the result (Bergman, 2008). Research design comprises sampling techniques, identification of population, questionnaire design or instrument and data collection.

However, for the smooth conduct of this research, the research design adopted for this study will be survey research approach. The choice of the survey method is due to the complexity, diversification and fragmentation of Nigeria construction industry. The survey research in this case was the research approach where one collects data from all or part of the population to assess the relative incidence, distribution and interrelation of naturally occurring variables.

3.3 Research Population

Population is a collection of elements about which we wish to make an inference this refers to a set of all possible cases of interest in a given research activity, it is a collection of objects or individuals whose properties are to be analysed, it could be classified into finite population (when the element of the population could be physically listed) and infinite population (when the element of the population could not be physically listed). The register of Abuja Business Directory has 255 construction firms registered with Abuja's business address only 51 had an idea or had adopted Modular Integrated Construction. This makes up the population size for the study.

However, the population for this research work consist of one professional (Architect, Quantity Surveyor, Civil Engineer and Builder) in the selected 51 construction firms that have made use of modular integrated construction in the past.

3.4 Sampling Technique

The sampling technique is the approach adopted for the selection of a sample from the population. The objective of every sampling strategy is to have a sample that represents the characteristics of the population especially the construction organisations that are spread all over the country Levy and Lemeshow (2008) asserted that sampling method is the scientific technique of selecting those sampling units that provides the required estimates with associated margins of uncertainty arising from investigating only a part not the whole.

Therefore, this research work adopted snowball sampling method because population is unknown and rare and it is tough to choose subjects to assemble them as samples for research. In other words, the study identified one professional from the identified firms that have used, have an idea or are considering adopting MIC were used which satisfied this study.

3.5 Sample Size

Out of the 255 construction firms domiciled in Abuja, only 51 had an idea or had adopted MIC, this formed the sample size of the study. An entire population will have to be sampled in small populations (i.e. less than 100) to achieve a desirable level of precision Therefore, 51 construction firms were considered for the purpose of the study, because they’ve either used or have an idea on MiC.

3.6 Method of Data Collection

The data collection is the most critical part of the study since the accuracy of the data is related to the success or failure of the research. The data for this research was obtained through questionnaires that was designed to assess the drivers and barriers and critical success factors for implementing modular integrated construction and the effect of modular integrated construction practice on building construction cost.

3.7 Research Instrument

The research instrument that was adopted for this research was questionnaire. The questionnaire was structured in two parts. The first part contains demographic profiles of the respondents, and the second part contains the technical aspects of research objectives and questions as shown in the appendix.

3.7.1 The questionnaire design

The questionnaire was designed in a closed ended format based on the research objectives and research questions. The choice of the questionnaire design scale was based on quantitative research approach adopted in this study. The questionnaire was designed in five (5) point Likert scales in order to provide the opportunity for the respondents to indicate their level of contribution, and satisfaction with statements made by means of ordinal scale. This was in line with Tam *et al.* (2007) concept that the reliability of the five (5) point scale is good and allows high range of answers to respondents compared to smaller point scale. The types of scale adopted in this research are: [5= very high, 4= high, 3= slightly high, 2= low and 1=very low]. During the course of designing questionnaire, efforts was made to ensure the necessary research question have covered all areas of interest. For example, the first section sought information on the demographic profile of the respondents, and these are academic qualification, type of profession, years of working experience, the capacity of respondent's involvement in the projects etc. The second section sought information on the technical aspect of the research.

3.8 Pilot Survey

The pilot survey was conducted in the preparation of this research work. The pilot study validated the research method and research approach that was adopted. It provided a trial run for the questionnaire which involves testing the technique before it was used to collect the data. The pilot survey provided the researcher with the preview of the type of responses that was anticipated and determines the optimum length of time in answering the questionnaire. It was helped to refine the data collection plans with respect to both content and the procedure that follows. A total of 20 respondents were used for the pilot study. The responses of the questions and the various comments was used to improve the final survey instrument. However, only the results from the final main survey are presented in this thesis.

3.9 Method of Data Analyses

The Statistical Package for Social Scientist (IBM SPSS) version 22 was the software used in data analysis. The method of data analysis that adopted for this research work induced descriptive analysis, relative important index (RII) and correlation analysis. The descriptive analysis was used examine the level of awareness. While relative important index was used to examine the drivers and barriers of the use of MIC.

3.9.1 Descriptive analysis

The descriptive method of analysis was adopted to summarise the sample, rather than use data to learn about the population and sample. It was also used to summarise transactions contained in the data set, that either represent the entire population or sample. The descriptive method of analysis was adopted to use the mean score to rank the opinion of the respondents.

3.9.2 The mean item score

The descriptive statistic is the arithmetic mean (X). This is used to calculate the average of a series of observations of a continuous variable. If a sample consists of several observations $X_1 ... X_n$, then the mean is calculated as: Mean X = $\frac{\sum(X1+X2+X3+\cdots Xn)}{N}$ Where x= the opinion of the respondents, N= total number of respondents.

The mean score was used to rank the causes of delayed payment in building projects. It was also used rank the mitigation measures to reduce delayed payment in building projects.

Table 3.1: Decision Rule for Mean Ranking

SCALE	***MEAN SCORE***	***Decision/ Remark***
5	4.50 to 5.00	Very High
4	3.50 to 4.49	High
3	2.50 to 3.49	Slightly High
2	1.50 to 2.49	Low
1	0.00 to 1.49	None

Source: Morenikeji (2006)

CHAPTER FOUR

4.0 DATA PRESENTATION, ANALYSIS AND DISCUSSION

4.1 Presentation of Respondents' Profile

The data for the study were gathered using a questionnaire. The questionnaire copies were administered to 51 professionals (Architect, Quantity surveyors, Civil Engineers and Builders) in the building construction industry in Abuja, out of which 50 questionnaires were retrieved and analysed. This section presents the profile of the respondents considered for data collection. The respondents profile is presented in Figure 4.1, 4.2 and Table 4.1.

The position occupied by the respondents, as shown in respondent Table 4.1 revealed that out of the 50 professionals sampled, 18 were site engineers, 15 were construction managers, 12 were project managers, and 6 were procurement officers. The study went on to categorise the respondents by profession: twenty were architects, twelve were civil/structural engineers, eleven were quantity surveyors, and seven were builders.

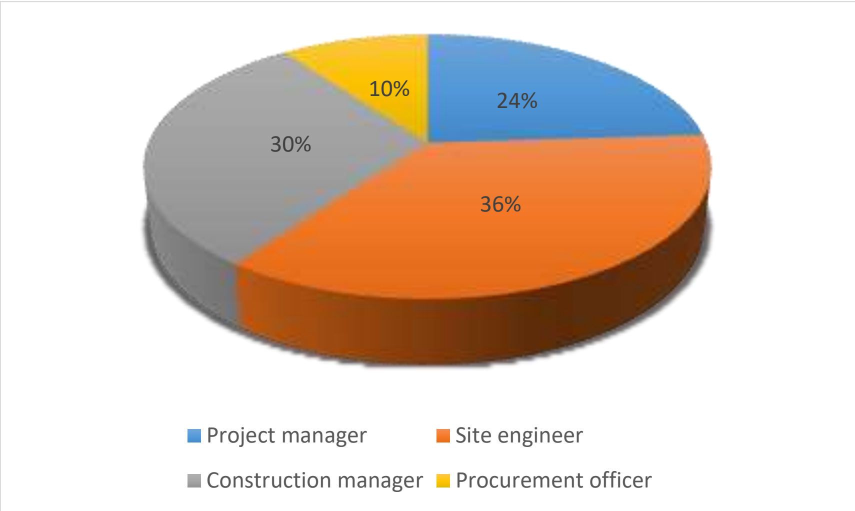

Figure 4.1: Position of Respondents

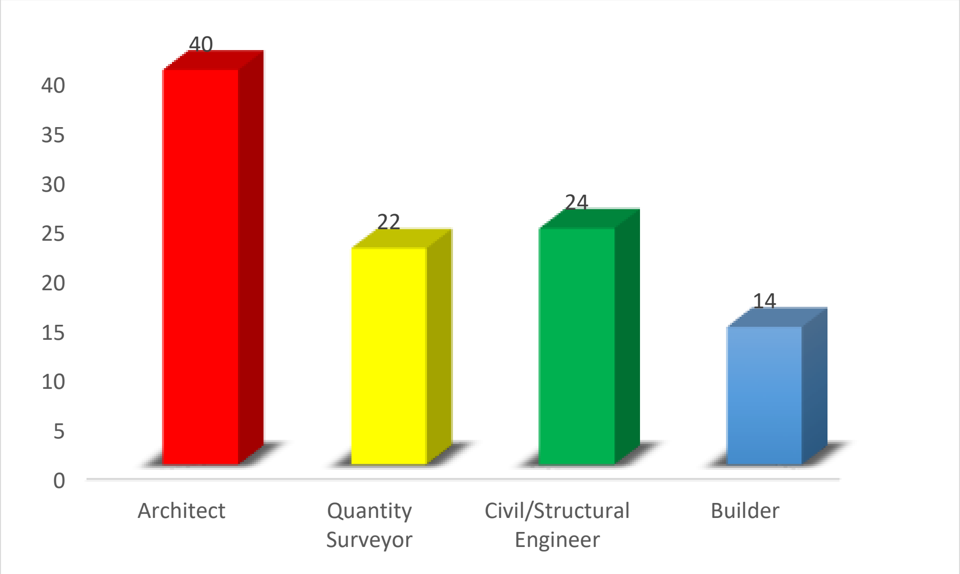

Figure 4.2: Profession of Respondents

It was also revealed from Table 4.1 that 54% of the respondents, representing the majority, are holders of bachelor's Degrees (BTech/BSc). This is followed by (MTech/MSc), which represents 32% of the respondents. Holders of HND, PGD, and Phd, representing the minority of the respondents, which constituted 6%, 4%, and 4% of the population of respondents, respectively. Notably, all the respondents are well educated, having at least a bachelor's degree. Based on their educational status, their responses are most likely credible. Table 4.1 also indicates that 10% of the respondents have between 1 and 5 years of experience; 18% of the respondents have between 5 and 10 years of experience; 40% of the respondents, representing the majority, have between 10 and 15 years of experience; 24% of the respondents have between 15 and 20 years of experience; and 8% of the respondents, representing the minority, have more than 20 years of experience.

This shows that the respondents are experienced enough to give reliable information needed for the study. In addition, the respondents all have some reasonable years of work experience in the field, so they are considered qualified to provide reliable data for the study. The data presented in Table 1 indicates that the majority (62%) of the respondents are familiar with modular construction as a building construction method. Only about 26% are unfamiliar with this construction method. This implies that professionals in the study area are, to a reasonable extent, aware of modular construction as a building development method.

4.2 Result and Presentation on the Drivers of the use of Modular Construction

The MIS analysis results of the drivers of the use of modular construction are summarised in Table 4.2.

Table 4.1: Drivers of the use of Modular Construction

SN	Drivers of the use of Modular Construction	MIS	Rank	Decision
1	Availability and accessibility of skilled and experienced factory labour force	4.38	1st	Important
2	Strict requirement for project quality control	4.36	2nd	Important
3	Need for improved construction safety	4.28	3rd	Important
4	Availability of skilled management and supervising team	4.28	3rd	Important
5	Availability of skilled onsite labour	4.08	5th	Important
6	Overall cost control requirement	3.80	6th	Important
7	Certainty of project completion date	3.52	7th	Important
8	Need to reduce neighbourhood and business disruption and noise during construction	3.48	8th	Less important
9	Stringent project cost and strict requirement for certainty	3.40	9th	Less important
	Average MIS	*3.95*		*Important*

As shown in Table 4.2, nine drivers for the use of modular construction were identified in the study area, out of which seven were important and two were less important. Table 4.2 indicated that the availability and accessibility of a skilled and experienced factory labour force were ranked 1st and 2nd, with a mean value of 4.38 being the most important driver. This was followed by strict requirements for project quality control, which ranked 2nd with a mean value of 4.36. Moreover, the need for improved construction safety and the availability of skilled management and supervising teams were ranked 3rd with a mean value of 4.28 and 4.28, respectively. Furthermore, the following drivers were less important: the need to reduce neighbourhood and business disruption and noise during construction; stringent project costs and strict requirements for certainty; and communication of programmes ranked 8th and 9th with a mean value of (3.48 and 3.40) respectively. Averagely, drivers of the use of modular construction are important (average MIS = 3.95).

4.3 Result and Presentation on the Barriers of the use of Modular Construction

The MIS analysis results of the barriers to the use of modular construction are summarised in Table 4.3.

Table 4.2: Barriers to the use of Modular Construction

SN	barriers to the use of Modular Construction	RII	Rank	Decision
1	Financial barriers.	4.54	1st	Very Important
2	Attitudinal barriers.	3.80	2nd	Important
3	Technical barriers.	3.80	2nd	Important
4	Policy barriers	3.74	4th	Important
5	Knowledge barriers	3.70	5th	Important
6	Industry barriers	3.60	6th	Important
7	Process barriers	3.58	7th	Important
8	Aesthetic barriers	2.88	8th	Less important
	Average MIS	***3.71***		*Important*

Eight barriers to the use of modular construction were identified in the study area as shown in Table 4.3, out of which seven were important and one was less important. Table 4.3 indicated that financial barriers were ranked 1st, with a mean value of 4.54%, being the most important barrier. This was followed by attitudinal barriers and technical barriers, ranked 2nd and 3rd with a mean value of (3.80 and 3.80) respectively. Moreover, policy barriers were ranked 4^{th} with a mean value of 3.74, knowledge barriers were ranked 5^{th} with a mean value of 3.70, and industry and process barriers were ranked 6th and 7^{th} with a mean value of 3.60 and 3.58, respectively. Lastly, aesthetic barriers ranked 8th with a mean value of 2.88, the least important barrier to the use of modular construction. Averagely, barriers to the use of modular construction are important (average MIS = 3.71).

The diffusion of MiC into the construction sector is disruptive and demands significant changes to some entrenched practices. Given that the construction industry is slow to adopt innovative solutions (Ruparathna and Hewage, 2015), the diffusion of MiC is battling a hostile welcome amid a complex host of barriers.

The studies of Hamzeh *et al.*, 2017; Rahman, 2014 corroborate the findings of this study by grouping the 120 barriers into attitudinal (10), industry (10), process (30), financial (15), technical (25), aesthetic (5), knowledge (15), and policy (10) barriers.

4.4 Result and Presentation on the Critical Success Factors for Implementing Modular Integrated Construction as a Building Construction Method

The MIS analysis results of the critical success factors for implementing modular integrated construction as a building construction method summarised in Table 4.4.

Table 4.3: critical success factors

SN	critical success factors	RII	Rank	Decision
1	Experienced workforce and technical capability	4.52	1st	Very Important
2	Adequate experience and knowledge of key players	4.48	2nd	Important
3	Effective coordination of on-site and off-site trades	4.36	2nd	Important
4	Robust drawing specification and early design freeze	4.18	4th	Important
5	Effective coordination of the supply chain segments	4.12	5th	Important
6	Extensive project planning, scheduling and control	4.06	6th	Important
7	Good working collaboration, communication and information sharing	3.76	7th	Important
8	Fabricator experience and capabilities in modules design and production	3.30	8th	Less Important
9	Availability and active involvement of key project team members from the earliest stage of the project	3.06	9th	Less Important
10	Standardization and mass production	3.04	10th	Less Important
11	Availability of sound local transport infrastructure	3.00	11th	Less Important
12	Realistic economic analysis, early decision and definition of project scope	2.98	12th	Less Important
13	Effective supply chain and execution risk management	2.96	13th	Less Important
14	Availability of skilled workforce, management and supervision team	2.94	14th	Less Important
15	Early completion and cost savings recognition	2.92	15th	Less Important
16	Alignment on MiC project drivers and modules architecture	2.88	16th	Less Important
17	Early advice from experts and consideration of MiC	2.80	17th	Less Important
18	Suitable procurement strategy and contracting	2.58	18th	Less Important
	Average MIS	***3.44***		Less Important

It was revealed from Table 4.4 that of the eighteen (18) critical success factors for implementing modular integrated construction as a building construction method, Experienced workforce and technical capability (MIS = 4.52), adequate experience and knowledge of key players (MIS = 4.48), effective coordination of on-site and off-site trades (MIS = 4.36), robust drawing specifications and early design freeze (MIS = 4.18), effective coordination of the supply chain segments (MIS = 4.12), extensive project planning, scheduling, and control (MIS = 4.06), and good working collaboration, communication, and information sharing (MIS = 3.76). On average, all the identified critical success factors for implementing modular integrated construction as a building construction method are less important (average MIS = 3.44). The basis of ranking in this study is plausible because previous reviews on CSFs have relied on the frequency of occurrence to rank the factors.

4.5 Effect of Modular Integrated Construction Practice on Building Construction Cost

Findings from the field survey reveal the MIS value for the effect of modular integrated construction practises on cost effectiveness, as shown in Table 4.5. Reduces the costs to design, develop, and/or maintain the project, with a MIS of 4.70, which is the most significant, ranked first. Followed by helping achieve accuracy of the cost estimate in the 2nd position with an MIS of 4.44. Also, reducing the cost of rework was ranked 3rd, with an MIS of 4.38. It reduces the waste of materials and was ranked 4th with a MIS of 4.34. Finally, reducing the overhead cost of the project was the least significant effect, ranked 9th with a MIS of 2.94. On average, all the identified effects of modular integrated construction practise on the cost effectiveness method are significant (MIS = 3.93).

Table 4.4: Effect of modular integrated construction practice on building construction cost

Effect of modular Integrated construction practice on building construction cost	**MIS**	**Rank**	**Decision**
Reduces the costs to design and develop and/or maintain the project	4.70	1st	Very significant
Helps achieve accuracy of the cost estimate	4.44	2nd	significant
Reduces the cost of rework	4.38	3rd	significant
Reduces the waste of materials	4.34	4th	significant
Reduces the cost of variation orders	4.32	5th	significant
Increases the Profit rate of project	4.28	6th	significant
Increases project cash flow	3.06	7th	Moderately significant
Reduces the material and equipment cost	3.00	8th	Moderately significant
Reduces the overhead cost of the project	2.94	9th	Moderately significant
Average MIS	***3.93***		***significant***

4.6 Factor Analysis for Critical Success Factors for Implementing Modular Integrated Construction as a Building Construction Method.

In Table 4.6, the KMO value is 0.594 and the Bartlett's test of sphericity is significant ($p<0.05$). The results of the reliability test, correlation matrix, Kaiser–Meyer-Olkin measure of sampling adequacy (KMO) and Bartlett's test of sphericity show that the data obtained is reliable and sufficient to conduct a factor analysis.

Table 4.5: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.594
Bartlett's Test of Sphericity	Approx. Chi-Square	345.489
	df	153
	Sig.	.000

The results of the principal component analysis are shown in Table 8 and the Scree plot (Figure 4.1). Based on Kaiser's criterion, seven components were extracted for having eigenvalues above 1.0 (3.921, 2.146, 1.920, 1.555, 1.283, 1.249 and 1.129). Component 1 with an eigenvalue of 3.921accounts for 21.78% of the variance in the dataset.

Component 2 with an eigenvalue of 2.146 accounts for 11.92% of the variance. Component 3 with an eigenvalue of 1.920 accounts for 10.66% of the variance. Component 4 with an eigenvalue of 1.555 accounts for 8.63% of the variance. Component 5 with an eigenvalue of 1.283 accounts for 7.13% of the variance in the dataset. Component 6vwith an eigenvalue of 1.249 accounts for 6.93% of the variance while Component 7 with an eigenvalue of 1.129accounts for 6.27% of the variance. Subsequently, all the seven components account for 73.35 % of the variation in the critical success factors for implementing modular integrated construction as a building construction method. Referring to the Cattell's scree plot in Figure 4.3, there are seven components above the point where the curve changes direction and becomes horizontal. These seven components should therefore be retained. This further confirms the result in Table 4.6 where seven components with eigenvalues greater than one were extracted based on Kaiser's criterion.

Tabl4e 4.6: Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.921	21.784	21.784	3.921	21.784	21.784	3.107	17.262	17.262
2	2.146	11.923	33.707	2.146	11.923	33.707	2.222	12.345	29.608
3	1.920	10.665	44.372	1.920	10.665	44.372	1.866	10.365	39.972
4	1.555	8.637	53.009	1.555	8.637	53.009	1.668	9.264	49.237
5	1.283	7.130	60.140	1.283	7.130	60.140	1.569	8.717	57.954
6	1.249	6.938	67.078	1.249	6.938	67.078	1.390	7.721	65.675
7	1.129	6.274	73.352	1.129	6.274	73.352	1.382	7.676	73.352
8	.862	4.790	78.142						
9	.824	4.576	82.717						
10	.626	3.480	86.197						
11	.597	3.314	89.511						
12	.508	2.820	92.331						
13	.413	2.295	94.626						
14	.348	1.932	96.558						
15	.267	1.484	98.042						
16	.175	.972	99.014						
17	.123	.681	99.695						
18	.055	.305	100.000						

Extraction Method: Principal Component Analysis.

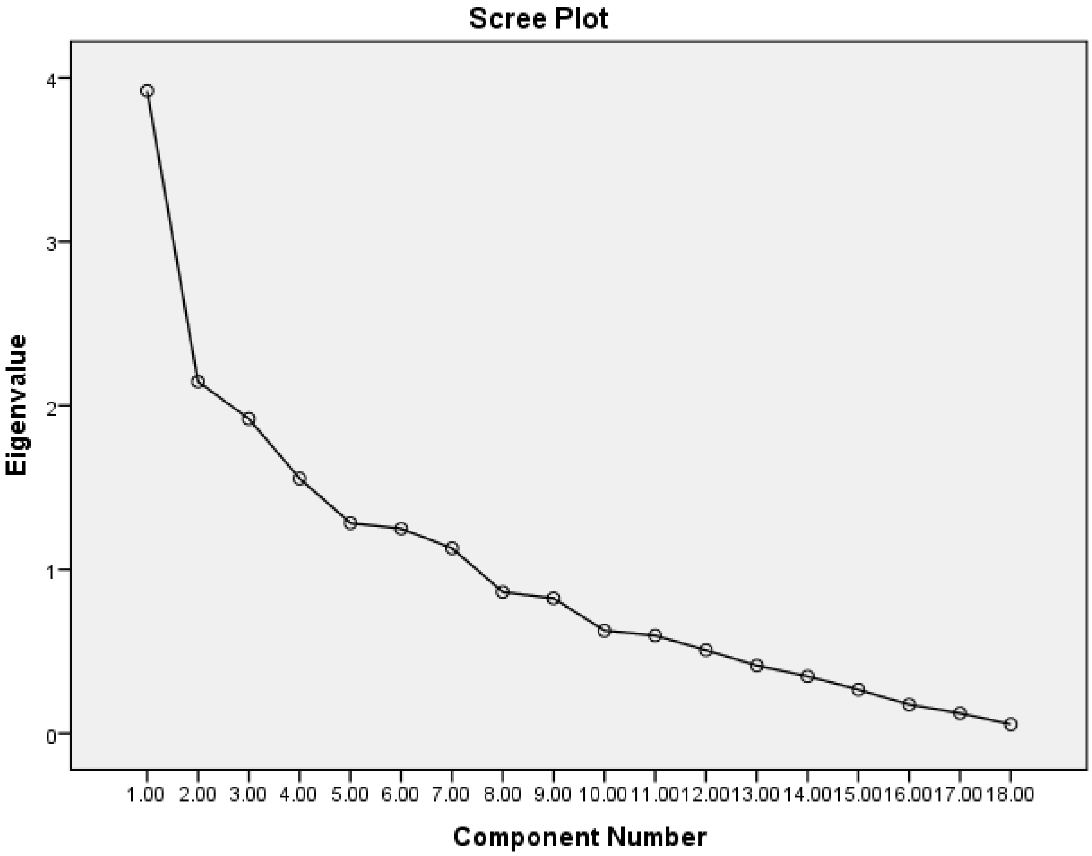

Figure 4.3: **Scree plot of the components**

Kaiser's criterion and Cattell's scree test were used to determine the seven factors to retain. Factor rotation based on the Varimax Orthogonal rotational technique was employed to reveal the pattern of loadings in a way that it would be easier to explain. Following previous studies, factors with absolute values less than 0.3 correlation loadings were sorted by size and suppressed to make the output easier to explain. The results of each of the seven extracted components and their variables are shown in Table 4.8.

Table 4.7: Rotated Component Matrix[a]

	Component						
	1	2	3	4	5	6	7
Adequate experience and knowledge of key players	.938						
Experienced workforce and technical capability	.908						
Effective coordination of on-site and off-site trades	.890						
Extensive project planning, scheduling and control		.891					
Effective coordination of the supply chain segments		.818					
Robust drawing specification and early design freeze	.523	.577	-.385				
Availability and active involvement of key project team members from the earliest stage of the project			.708				
Effective supply chain and execution risk management		.327	.570				
Early advice from experts and consideration of MiC			-.551	.428	-.330	-.331	
Good working collaboration, communication and information sharing			.457		.365	-.348	-.380
Availability of sound local transport infrastructure				.873			
Alignment on MiC project drivers and modules architecture				.565		.304	
Early completion and cost savings recognition			.463	.480			

Standardization and mass production					.773		
Fabricator experience and capabilities in modules design and production					.703		
Suitable procurement strategy and contracting						.878	
Realistic economic analysis, early decision and definition of project scope							.814
Availability of skilled workforce, management and supervision team						-.438	.555

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 18 iterations.

From Table 4.8 seven components are extracted as critical success factors for implementing modular integrated construction as a building construction method. The first component has significant correlation loadings for a group of four variables, namely: The Adequate experience and knowledge of key players, experienced workforce and technical capability, Effective coordination of on-site and off-site trades and Robust drawing specification and early design freeze. These variables are based on previous studies. The second component has significant correlation loadings for a group of four variables. The third component has significant correlation loadings for a group of four variables. The fourth component has significant correlation loadings for a group of four variables. The fifth component has significant correlation loadings for a group of three variables. The sixth component has significant correlation loadings for a group of two variables. The seventh component has significant correlation loadings for a group of two variables. Overall, the findings imply that dwelling attributes play an important role. The findings are also consistent with previous findings on Critical success factors for modular integrated construction projects where it was concluded that these shared CSFs can be used to develop decision support systems, enabling the prediction of project success.

To better contextualize the components, the components were renamed based on the factors under each of them as shown below:

- **Component 1** which include (Adequate experience and knowledge of key players [0.938]), (Experienced workforce and technical capability [0.908]), (Effective coordination of on-site and off-site trades [0.890]), and (Robust drawing specification and early design freeze [0.523]) was renamed as "***Robust design specification and early design freeze***".
- **Component 2** which include (Extensive project planning, scheduling and control [0.891]), (Effective coordination of the supply chain segments [0.818]), (Robust drawing specification and early design freeze [0.577), and (Effective supply chain and execution risk management [0.327]) was renamed as "***Effective supply chain management***".
- **Component 3** which include (Availability and active involvement of key project team members from the earliest stage of the project [0.708]), (Effective supply chain and execution risk management) [0.570]), (Early completion and cost savings recognition [0.463]), and (Good working collaboration, communication and information sharing [0.457]) was renamed as "***Early involvement of key participants***".
- **Component 4** which include (Early advice from experts and consideration of MiC [0.428]), (Standardization and mass production [0.873]), (Alignment on MiC project drivers and modules architecture [0.565]), and (Early completion and cost savings recognition Standardization and mass production [0.480]) was renamed as "***Early involvement of key participants***".

- **Component 5** which include (Good working collaboration, communication and information sharing [0.365]), (Standardization and mass production [0.703]), and (Fabricator experience and capabilities in modules design and production. [0.773) was renamed as "***Relevant experience and knowledge of key players***".
- **Component 6** which include (Alignment on MiC project drivers and modules architecture [0.304]), and (Suitable procurement strategy and contracting (0.878) (was renamed as "***Suitable procurement strategy***".
- **Component 7** which include (Realistic economic analysis, early decision and definition of project scope [0.814]) and (Availability of skilled workforce, management and supervision team [0.555]) was renamed as "***Relevant experience and knowledge of key players***

4.7 Summary of Findings

Based on the findings from the results of data analyses undertaken in this study, the following are the major findings:

i. The study identified availability and accessibility of skilled and experienced factory labour force (MIS = 4.38); strict requirement for project quality control (MIS = 4.36); need for improved construction safety (MIS = 4.28); availability of skilled management and supervising team (MIS = 4.28); and availability of skilled onsite labour (MIS = 4.08) are the most important drivers. The less significant drivers for the use of modular construction are the need to reduce neighbourhood and business disruption and noise during construction (MIS = 3.48) and stringent project cost and strict requirement for certainty (MIS = 3.40). On the average, all the drivers of the use of modular construction are important (average MIS = 3.95).

ii. The study identified financial barriers. (MIS = 4.54) is very important. The least important barrier to the use of modular construction is aesthetic barriers (MIS =

2.88). On the average, all the barriers to the use of modular construction are important (average MIS = 3.71).

iii. The most important critical success factors for implementing modular integrated construction as a building construction method are an experienced workforce and technical capability (MIS = 4.52). The least important factor is a suitable procurement strategy and contracting (MIS = 2.58). On average, all the identified critical success factors for implementing modular integrated construction as a building construction method are less important (average MIS = 3.44).

iv. The most significant effect of modular integrated construction practises on building is that they reduce the costs of design and development and/or maintenance of the project (MIS = 4.70). The least significant effect of modular integrated construction practises on cost effectiveness is that they reduce the overhead cost of the project (MIS = 2.94). On average, all the identified effects of modular integrated construction practise on the cost effectiveness method are significant (MIS = 3.93).

v. Factor analysis for critical success factors for implementing modular integrated construction as a building construction method revealed the KMO value is 0.594 and the Bartlett's test of sphericity is significant (p 0.05). The results of the reliability test, correlation matrix, Kaiser–Meyer–Olkin measure of sampling adequacy (KMO), and Bartlett's test of sphericity show that the data obtained is reliable and sufficient to conduct a factor analysis.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In view of the findings of this study, the study assessed the utilisation of modular integrated construction as a building construction method in Nigeria. Data was collected from 50 construction sites in Abuja with a response rate of 98.03%. The analysis of the data was carried out with the use of percentage, mean item score, and factor analysis. The results of the analysis carried out led to the conclusions made in this chapter. The most important drivers for the use of modular construction are the availability and accessibility of a skilled and experienced factory labour force; strict requirements for project quality control; the need for improved construction safety; the availability of skilled management and supervising team; and the availability of skilled onsite labour. On average, all the drivers of the use of modular construction are important. The most important barrier to the use of modular construction is financial barriers. Aesthetic barriers are the least important barriers to the use of modular construction. On average, all the barriers to the use of modular construction are important. The most important critical success factors for implementing modular integrated construction as a building construction method are an experienced workforce and technical capability. The least important factor is a suitable procurement strategy and contracting. On average, all the identified critical success factors for implementing modular integrated construction as a building construction method are less important. The most significant effect of modular integrated construction practises on cost effectiveness is that they reduce the costs of design, development, and/or maintenance of the project. The least significant effect of modular integrated construction practises on cost effectiveness is this reduces the overhead cost of the project. On average, all the identified effects of modular integrated construction practise on the cost effectiveness method are significant. Factor analysis for critical success factors for implementing modular integrated construction as a building construction method revealed that the Bartlett's test of sphericity is significant. The results of the reliability test, correlation matrix, Kaiser–Meyer–Olkin measure of sampling adequacy (KMO), and Bartlett's test of sphericity show that the data obtained is reliable and sufficient to conduct a factor analysis. It can therefore be concluded that by knowing the current opportunities and challenges involved in the implementation of modular methods in the urban environment, practitioners would promote, plan, and implement modular methods better in the urban environment and achieve higher levels of modularization, which will then contribute to the productivity growth in the construction industry.

5.2 Recommendations

As a result of the conclusions made in this study, the following were recommended:

1. The study recommends wide adoption of prefab system considering their prospects of ensuring quality as a result of better supervision and suggests outsourcing on critical areas of organisations' logistic weaknesses to minimize the problem of higher initial costs.
2. Professional bodies should hold seminars from time to time to educate and enlighten professionals on the requirements and advantages that modular building may provide in terms of cost efficiency.
3. To increase practitioners' understanding, all professional institutions in the built environment should emphasise modular building technique practise in their Continuous Professional Development (CPD) programmes.

5.3 Contribution to Knowledge

The study has made following significant contributions to the body of knowledge:

1. The study provides information on the drivers of the use of modular construction were
2. The study also identified the barriers to the use of modular construction.
3. The Critical Success Factors for Implementing Modular Integrated Construction as a Building Construction Method in the Study were also highlighted.
4. It also showed the professional that the costs to design, build, and/or maintain the project were reduced by using modular integrated construction practices. This has a MIS of 4.70, which is the most important effect on cost effectiveness.

5.4 Areas for Further Studies

In the light of the limitations of this study, the following areas are suggested for further research:

i. To overcome this barrier, further studies need to be conducted related to managing building code compliance and the acceptance of modules by the different jurisdictions.

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APPENDIX

DEPARTMENT OF QUANTITY SURVEYING

SCHOOL OF ENVIRONMENTAL TECHNOLOGY

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

RESEARCH QUESTIONNAIRE

Date:---------------------------

Dear Sir/Ma,

I am a M. Tech student of the above named department and institution, carrying out a research on the topic: **ASSESSMENT OF THE UTILISATION OF MODULAR INTEGRATED CONSTRUCTION ON THE COST EFFECTIVENESS OF BUILDING PROJECTS IN ABUJA.**

The research seek your co-operation to supply correct answers to the questions asked to the best of your knowledge. Every answer will be treated in strict confidence and would be utilized only for the purpose of this study.

Thanks for your cooperation.

Yours faithfully,

IDRIS, ADAMU
(MTECH/SET/2019/)
(Project student).

SECTION A: General Information of Respondent and Organization

Q1. Please provide information about the respondent as requested by selecting one of the options provided.

1. Position of Respondent in Organization…………………………………………………...
2. Profession of respondent (**please tick as appropriate**)
   a. Quantity Surveyor ☐ b. Architect ☐ c. Builder ☐ d. Civil ☐ Engineer ☐
   e. Town Planner ☐ f. Land Surveyor ☐ g. Estate Surveyor
3. Are you a registered member of your Profession? **(please tick as appropriate**)
   a. Yes ☐ b. No ☐
4. Highest academic qualification (**please tick as appropriate**)
   a. HND ☐ b. B. Sc/B. Tech ☐ c. PGD ☐ d. Msc ☐ e. PhD ☐
5. Age group of respondents **(please tick as appropriate)**
   a. 21-30 ☐ b. 31-40 ☐ c. 41-50 ☐ d. 50 above ☐
6. For how long have you been working in the Nigerian construction industry? **(please tick as appropriate)**
   a. Less than 5 years ☐ b. 5-10 years ☐ c. 10-15 years ☐ d. 20 years ☐

20 years above ☐

7. Are you aware of modular construction as a building construction method
   a. Very aware ☐ b. b Aware ☐ c. Undecided ☐ d. Less ☐ aware ☐

Not aware

SECTION B: Drivers of the use of Modular Construction

Q8. Please tick (√) appropriately in the space provided using a Likert scale (1-5) the following drivers of the use of modular construction

S/N	Drivers	Strongly Agree 5	Agree 4	Averagely Agree 3	Disagree 2	Strongly Not disagree 1
1	Availability and accessibility of skilled and experienced factory labour force					
2	Availability of skilled management and supervising team					
3	Need for improved construction safety					
4	Strict requirement for project quality control					
5	Availability of skilled onsite labour					
6	Overall cost control requirement					
7	Certainty of project completion date					
8	Stringent project cost and strict requirement for certainty					
9	Need to reduce neighbourhood and business disruption and noise during construction					
10	Need to reduce neighbourhood and business disruption and noise during construction					

SECTION C: Barriers of The Use Of Modular Integrated Construction Method

Q4. The following has been identified as the **barriers of the use of modular integrated construction method**. Please tick (√) appropriately in the space provided using a Likert scale (1-5) the following

S/N	Barriers	Strongly Agree 5	Agree 4	Averagely Agree 3	Disagree 2	Strongly Not disagree 1
1	Attitudinal barriers.					
2	Knowledge barriers					
3	Technical barriers.					
4	Financial barriers.					
5	Process barriers					
6	Policy barriers					
7	Industry barriers					
8	Aesthetic barriers					

SECTION D: Critical Success Factors for Implementing Modular Integrated Construction As A Building Construction Method.

Q5. Please tick (√) appropriately in the space provided using a Likert scale (1-5) the following critical success factors for implementing modular integrated construction as a building construction method.

S/N	Critical Success Factors	Strongly Agree 5	Agree 4	Averagely Agree 3	Disagree 2	Strongly Not disagree 1
1	Robust drawing specification and early design freeze					
2	Adequate experience and knowledge of key players					
3	Standardization and mass production					
4	Extensive project planning,					

	scheduling and control					
5	Good working collaboration, communication and information sharing					
6	Effective coordination of the supply chain segments					
7	Fabricator experience and capabilities in modules design and production					
8	Suitable procurement strategy and contracting					
9	Early advice from experts and consideration of MiC					
10	Experienced workforce and technical capability					
11	Effective coordination of on-site and off-site trades					
12	Alignment on MiC project drivers and modules architecture					
13	Availability of sound local transport infrastructure					
14	Early completion and cost savings recognition					
15	Availability of skilled workforce, management and supervision team					
16	Realistic economic analysis, early decision and					

	definition of project scope					
17	Availability and active involvement of key project team members from the earliest stage of the project					
18	Effective supply chain and execution risk management					

SECTION E: EFFECT OF MODULAR INTEGRATED CONSTRUCTION PRACTICE ON COST PERFORMANCE.

Q5. Please tick (√) appropriately in the space provided using a Likert scale (1-4) the following effect of modular Integrated construction practice on cost performance.

S/N	**Critical Success Factors**	**Never 1**	**Rarely 2**	**Sometimes 3**	**Always 4**
1	Reduces the waste of materials				
2	Reduces the cost of rework				
3	Helps achieve accuracy of the cost estimate				
4	Reduces the costs to design and develop and/or maintain the project				
5	Increases the Profit rate of project				
6	Reduces the cost of variation orders				
7	Reduces the overhead cost of the project				
8	Increases project cash flow				
9	Reduces the material and equipment cost				
10	Reduces the cost of travel and expenses a well as cost to train				