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Assessment of the Utilisation of Modular Integrated Construction on the Cost Effectiveness of Building Projects in Abuja.

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Abstract

This study assessed the utilisation of modular integrated construction as a building construction method in Nigeria with a view to ensuring cost effectiveness in building construction projects. 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). 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 were recommended to enhance the adoption of the modular construction method by professionals to ensure cost effectiveness in building construction projects.*

Introduction

Building construction can be an arduous process, rife with complications ranging from extreme weather conditions to work at excessive height and with limited access. 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. 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, 2014).

Literatures have demonstrated the impact of modular construction on productivity on major capital construction projects, the natural environment, human health and economy (Wei and 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; Adebisi and John, 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 (Buratti et al., 2014; 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 (Akinboade and Mkowena, 2012). Therefore, this research assessed the utilization of Modular Integrated Construction as a building construction method in Nigeria with a view to ensure cost effectiveness in building construction projects. In order to achieve this aim, the following objectives were formulated:

i. To examine the barriers of the use of Modular Construction.
ii. To examine the drivers of the use of Modular Construction.
iii. To examine 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 cost effectiveness

LITERATURE REVIEW

Barriers to the adoption of MiC

The adoption of MiC in the construction industry is a classic example of innovation diffusion in the sector (Lawrence 2017). According to Lawrence

(2017), 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.

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*, 2018). 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 (Lopez, and Froese, 2016) 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. Adebisi and John (2016), 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.

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 2019a). 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.,* 2018a). 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 (2007) 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).

RESEARCH METHODOLOGY

A quantitative research approach was adopted in this study. The use of structured questionnaires was employed for data collection in order to achieve the study's objectives. The mean item score (MIS) was used to analyse the collected data. The targeted population for this research work consist of the professionals in the selected 255 construction firms that have made use of modular integrated construction in the past. 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. Therefore, this research work adopted purposive sampling method because of its ease of accessibility for the researcher to gather data. In other words, the study identified professionals that have used, have an idea or are considering adopting MIC were used which satisfied this study. The questionnaire (designed in a five-point Likert scale format) addressed issues relating to the research objectives respectively.

RESULTS AND DISCUSSION

Result and Discussions 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 1.

Table 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 1, 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).

Result and Discussions 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 2.

Table 2: Barriers to the use of Modular Construction

S/N	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	***3.7***		***Important***

Eight barriers to the use of modular construction were identified in the study area as shown in Table 2, out of which seven were important and one was less important. Table 2 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 4th with a mean value of 3.74, knowledge barriers were ranked 5th with a mean value of 3.70, and industry and process barriers were ranked 6th and 7th 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.

Result and Discussions 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 3

Table 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	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 3 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 (AntwiAfari et al., 2018; Osei-Kyei & Chan, 2015).

Effect of modular Integrated construction practice on cost effectiveness

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 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: Effect of modular Integrated construction practice on cost effectiveness

Effect of modular Integrated construction practice 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	7th 3.06	Moderately significant
Reduces the material and equipment cost	8th 3.00	Moderately significant
Reduces the overhead cost of the project	9th 2.94	Moderately significant
Average MIS	***3.93***	***significant***

CONCLUSION AND RECOMMENDATIONS

Literature has demonstrated the impact of modular construction on productivity on major capital construction projects, the natural environment, human health, and the economy. In view of this, the study assessed the utilisation of modular integrated construction as a building construction method in Nigeria with a view to ensuring cost effectiveness in building construction projects. 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. In view of the findings and conclusions of this study, the following recommendations were made:

1. Professionals should be encouraged to produce cheap dwelling designs that may employ the modular construction approach in the research region in order to assure cost efficiency in constructing construction projects. This is required since some of them are still unaware of the modular building technology or are aware of it but have not integrated it into their housing project ideas.
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.

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