Barriers to Successful Adoption of Design for Manufacture and Assembly in Nigeria

Wusu Godoyon[1], Alaka Hafiz[1], Ajayi Saheed[2], Raphael Oseghale[3] and Wasiu Yusuf[1]

[1]*Big Data Technologies and Innovation Laboratory, Hertfordshire Business School, University of Hertfordshire, Hatfield, UK.*

[2]*School of Built Environment, Engineering and Computing, Leeds Beckett University, Leeds, UK.*

[3]*Department of Management, Leadership and Organization, Hertfordshire Business School, University of Hertfordshire, Hatfield, UK.*

ABSTRACT

Shelter, since time immemorial, has been and will continue to be a vital basic human need. Notably, the need for shelter will continue to increase following increase in world population. However, the current traditional construction methods deployed in the construction of properties are slow as well as experiences cost over-run despite being expensive at take-off. Furthermore, current construction methods do not strengthen the government, private or Public-Private Partnership's efforts in combating housing deficits due to Nigeria's rising population. This paper thus proposes to examine the causes of low Design for Manufacture and Assembly (DfMA) adoption in Nigeria.

Literature relating to Design for Manufacture and Assembly (DfMA) and its adoption were sourced through Google Scholar and Scopus using key search words such as adoption, Design for Manufacture and Assembly, Offsite Construction and Prefab Constructions and names of key authors on the subject. Literature search was limited to between 2000 to 2021. The key factors identified in the literature were utilized in developing the questionnaire. A pilot survey was used to test the questionnaire before it was administered to relevant key players in the Nigerian construction industry for responses.

It emerged that most building designers are unwilling to embracing the idea of DfMA due to the resources in terms of cost and time required to train for its application. There are numerous other factors that have mitigated the institutionalization of the approach. A viable solution to this issue of building designers not wanting to re-train is to deploy Artificial Intelligence (AI) and Machine Learning to automatically generate DfMA concept designs that the building designers can subsequently upgrade into a complete design. Also, awareness of DfMA should be raised among players in the building industry. Finally, government policies should be deployed to create an enabling environment for DfMA construction approach to thrive.

Keywords: Adoption, Building Industry, Construction, DfMA, Shelter.

1. INTRODUCTION

Shelter, from time immemorial, has been and will continue to remain one of the vital basic human needs. As the world population increases, the demand for affordable shelter becomes a rising issue around the globe. World population, which was 6.115 billion people in the year 2000, stands today at 7.8 billion, indicating a 27.55% growth and is expected to hit 9.8 billion by 2050 (UNESCO, 2019). The population of Africa is expected to increase by over 1.1 billion by 2050 (YaleOnline, 2020), making it the continent with the highest population in future. In most countries of the world, there is a sprawling population in urban areas with large migration from rural areas as citizens search for greener pastures (Davoudi, S, & Stead, D., 2002).

Unarguably, there is a massive shortage of homes around the globe, and trying to address current housing challenges have recorded very little success (Badir, Kadir and Hashim, 2002). For example, in the United Kingdom (UK), there is an all-time housing shortage with millions of citizens without a home. (Griffith & Jefferys, 2013). Similarly, the United States (US) has witnessed a decline of below 42% in house owners below 35 years. (*A New Approach to Solving the US Housing Crisis (SSIR)*, 2018). Japan and China are employing every means possible to move people away from sleeping on the streets, especially in the urban areas (Li, 2011). Nigeria has recorded many failed proposed housing solutions (Lau *et al.*, 2017), while Ghana and South Africa still have more than half of their populations without a low-cost house. (Badir, Kadir and Hashim, 2002). This housing challenge seen in most places is not to say success is not without success in some countries as can be seen in Singapore, where estimates suggest that authorities in Singapore have managed to provide housing for slightly over 80% of its 5.4milion population (Lye, 2020., Bryson, 2019).

The current construction method employed in most Nigerian construction sites is mostly the traditional construction method. It is slow and it experiences cost over-run despite being expensive at take-off (Gbadamosi et al., 2020). It is time-consuming, experiences a significant number of on and off-site accidents. More so, it does not attract more workers into the industry ((Wang et al., 2020., Alexandra, 2020). At its best, traditional construction method should have been limited to remote areas of rural regions. Housing shortage, which is growing in inverse proportion to population rise, especially in the urban areas as a result of migration, cannot be restrained by the current traditional approaches. (World Economic Forum, 2019). In a bid to curb this growing trend, measures need to be put in place at the earliest time possible to forestall the negative impact of this development globally (Griffith & Jeffreys, 2013).

An effective and fast-Industrial Building System (IBS) that can address the challenges associated with the current traditional construction method is DfMA if Africa wants to address its housing challenge (Charef et al., 2019). Few on-site experimentations have revealed that Design for Manufacture and Assembly (DfMA) seems to be a quick way out of the woods, despite any initial resistance to the proposed construction approach (Charef et al., 2019). In agreement, extant studies suggest that material waste would be reduced if

construction expert can think of assembly production using factory means (Chen & Lu, 2018). DfMA is faster, less energy-consuming, more environmentally friendly since it generates less CO2 which causes greenhouse effects, and it is safer to work on during construction and maintenance. (Azli, 2014). DfMA homes are more eco-friendly than traditionally built structures (Antony & Arunkumar, 2020). Key players in the construction industry are aware of the challenges associated with current traditional approaches and that DfMA is the possible way out. The central challenge facing DfMA and its adoption is how to replace a good number of building designers who are trained to 'design to construct' (i.e., designing according to traditional methods) with those trained to design for assembly (Lu et al., 2021). Another way out is how to create an enabling environment to encourage the adoption of DfMA. One way out of this situation is to re-train the existing building designers and re-formulate encouraging and favourable policies.

The case of Singapore is a good example of a nation that has managed to (to some reasonable extent) forestall the growing trend of homelessness consistent with rising population as a result of birth and migration. Through the use of Design for Manufacture and Assembly (DfMA) approach to building construction, it has provided shelter for most of her citizens. (Shang, Pheng and Gina, 2020). While frantic effort to close the housing shortage gap has been made in many European cities (Tubman, 2020) and American states over the years using DfMA (Badir, Kadir and Hashim, 2002), African countries are yet to rise to the challenge (Rahimian et al., 2017). The UK and US governments invested millions of pounds and dollars respectively on research and pilot projects to address housing shortage. More so, governments in both instances developed policies to discourage using traditional construction approach which cannot deliver the required houses within the specified time frame. (Gao, Low, & Nair, 2018; Lu et al., 2021).

With the numerous advantages of DfMA being outlined in the literature, Africa is yet to embrace this new building methodology. Not that no efforts have been geared towards adopting DfMA usage, but such is nowhere matching the population explosion noticed in this region. Rahimian et al. (2017) noted that Nigeria has a housing deficit challenge of over 17 million in its major cities. The current construction methods have not corroborated government, private, or public-private partnerships to address the housing shortage in Nigeria.

Many of these building designers are not embracing DfMA because of the cost and time required to train for it. A viable solution to this issue of building designers not wanting to re-train is deploying Artificial Intelligence (AI) through Machine Learning generate DfMA concept designs automatically. The building designers can subsequently upgrade the AI model into a complete design (Ajayi, Brinlow-Harris, Alaka, & Dauda, 2019). AI will employ digital technology to improve manufacturing techniques and produce more energy-efficient structures, thereby saving time and cost amidst other factors. (Tan et al., 2020). Leaders of the African continent need to emulate the European Union to formulate clear-cut policies on the need to adopt DfMA in addressing its housing challenges.

Based on the above discussion, this paper proposes to examine the causes of low (DfMA) adoption in Nigeria.

2. METHODOLOGY

Literature relating to DfMA and its adoption were sourced through scholarly search engines like Google Scholar and Scopus. Key search words and phrases such as adoption, Design for Manufacture and Assembly, Offsite Construction and Prefab Constructions, and key authors' names were used during the literature survey. Specifically, research published on the subject between 2000 to 2021 were considered. A review of these papers informed the potential critical factors responsible for low DfMA adoption in Nigeria.

The factors that evolved among various key players of the construction industry towards DfMA from the literature studies revolve around policies affecting production and importation, cultural heritage and beliefs, attitudinal reactions, accessibility to funds, belief in the functional properties of DfMA, ease of workability and awareness. In addition, the factors pin-pointed some reactionary displays of interest in adopting DfMA as a construction methodology. These factors observed were used to develop a set questionnaire piloted with seven carefully selected participants; five of whom had construction background and have at a time or the other designed or recommended off-site construction materials for use. The other two were non-subject experts. Some observations such as tenses restructuring, spelling mistakes, regrouping of factors under related headings were made on the questionnaire, others were debated, and necessary corrections were effected. The questionnaire was developed in Microsoft form. The form link was administered to relevant key players in the Nigerian construction industry through e-mails and social media platforms for responses. The targeted responders were architects, civil/structural engineers, electrical engineers, mechanical engineers, building engineers, town/urban planners, quantity surveyors, contractors, academics and real estate investors and developers because they are believed to be actively involved in everyday construction processes in the country. They were considered as being involved in making and taking decisions bordering around the choice of building materials to be used on projects. Over 330 forms were sent out. Responses received within twelve hours was over fifty, and almost a hundred responses under sixty hours. The average response duration was 10.31 minutes.

3. MAIN DISCUSSION

The various factors extracted from literature were put under some headings as stated earlier. These factors are government policies on production, government policies on importation, cultural heritage factors about DfMA (i.e., being used to a style of building as a result of living in an environment/location, e.g., belief in the use of thatched roof on a round building in northern Nigeria.), historical factors (failure of DfMA in places where it was used), belief system (religious beliefs on building type and style), environmental factors (weather, climate, etc.). Factors such as designers' attitude, construction site managers, construction site workers, end-users/ building occupiers, client/ investor desire to use DfMA for construction were also examined. Awareness of DfMA by designers, awareness of DfMA by construction managers, awareness of DfMA by construction site workers, awareness of DfMA by end-users/ building occupiers, awareness of DfMA by client, awareness of

DfMA by government, level of accessibility to loans, accessibility to favourable exchange rate, level of availability of bespoke DfMA manufacturing company, availability of new or amended form of construction contracts that focus on DfMA, availability of contract documentation relating to DfMA, supply chain integration for DFMA, Supply chain management for DfMA were also looked at. Technological Advancement (DfMA Installation technique), level of availability of in-house DfMA design expertise for manufacturing companies, level of in-house DfMA building expertise for construction companies, level of availability of skilled personnel at Design Companies, level of availability of skilled building personnel on construction site, Construction knowledge of DfMA among Construction professional bodies in Nigeria, level of training/education in Nigerian universities on DfMA designs, level of guidance of BIM implementation and utilization on DfMA, Cost of DfMA Components and Cost of DfMA Installation were also included in the questionnaire.

Analyzing the results following after responses gathered from the questionnaire using SPSS, a reliability factor of 0.877 was realized as shown in Fig. 1

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.877	.905	39

Fig 1: Cronbach's Alpha Index

Examining the factors displayed in Fig. 2 below, Government policies on importation and production have more substantial adverse effect on adoption while cultural and historical factors have a relatively neutral impact on adoption. Environmental factors have the least damaging impact on DfMA adoption.

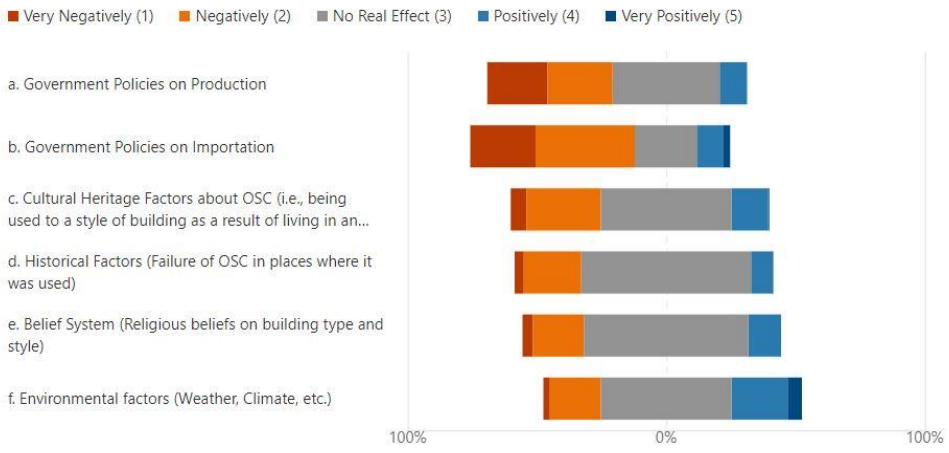

Fig. 2: Policy, Cultural, Historical and Environment Impact on DfMA Adoption

Examining the impacts of attitudes toward adoption of DfMA in Nigeria, the questionnaire showed that construction site professionals and designers have a more encouraging attitude towards adoption. End users, investors, clients and building occupiers have a relatively neutral attitude towards adopting DfMA while site workers and government have a discouraging attitude towards DfMA adoption as shown in *Fig. 3.*

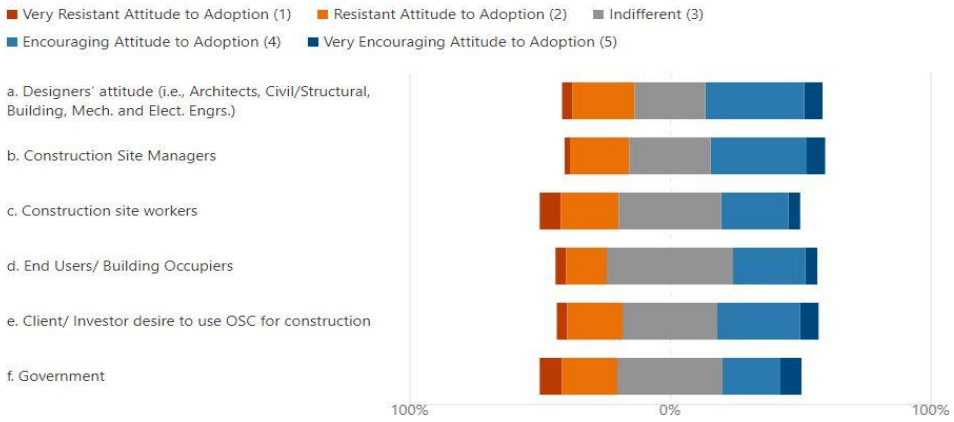

Fig. 3: Attitudinal Impact of Key Players in Nigeria Construction Industry on DfMA Adoption

The questionnaire further indicated in Fig. 4 that clients, end-users/building occupiers, construction site workers and designers are less aware of DfMA usage in the construction industry.

Fig. 4: Awareness Impact of Key Players in Nigeria Construction Industry on DfMA Adoption

Fig. 5 shows that level of accessibility to loans, accessibility to a favourable exchange rate, level of availability of bespoke DFMA manufacturing company, availability of new or amended form of construction contracts specifically focusing on DFMA together do not encourage the adoption of DfMA in Nigeria.

Fig 5: Finance and Construction Document accessibility level of Key Players in Nigeria Construction Industry on DfMA Adoption.

Fig 6 suggests that there is a level of availability of skilled personnel at design companies and skilled building personnel on construction site regarding DfMA usage. The figure further shows that Supply chain integration for DFMA, Supply chain management for DFMA, Technological Advancement (DFMA Installation technique), in-house DFMA design expertise for manufacturing companies, in-house DFMA building expertise for construction companies are not readily available. Construction knowledge of DFMA among construction professional bodies in Nigeria, Level of training/education in Nigerian universities on DFMA designs, level of guidance of BIM implementation and utilization on DFMA have low availability regarding DfMA adoption in Nigeria.

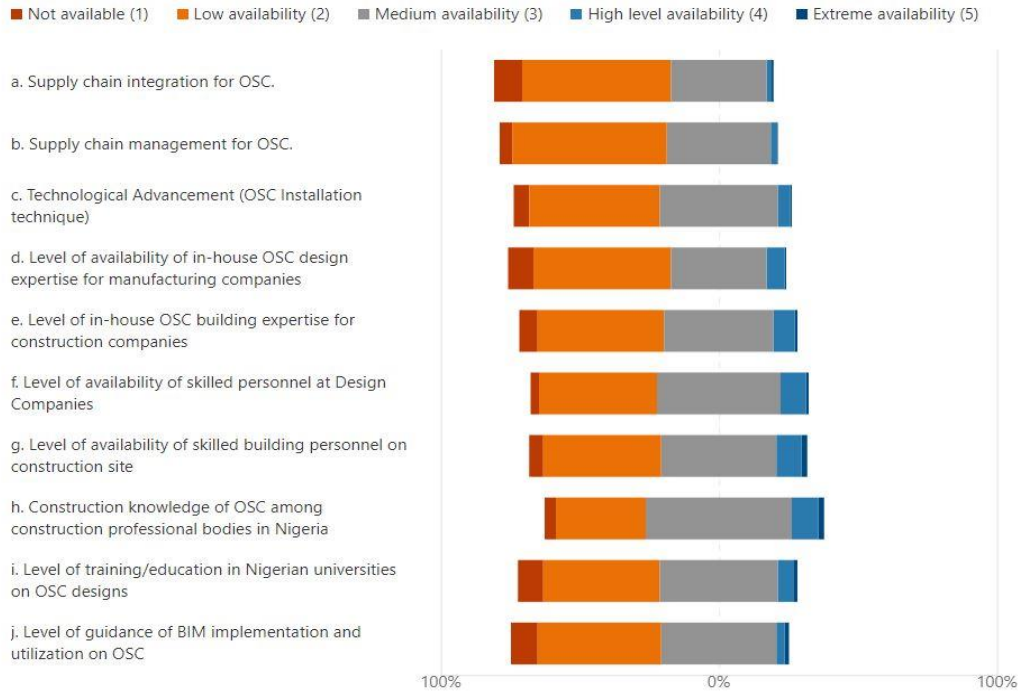

Fig. 6: Supply chain, Training and Skill availability level of Key Players in Nigeria Construction Industry on DfMA Adoption.

Fig. 7: DfMA components and installation cost comparism on DfMA Adoption.

Fig. 7 from the questionnaire informs that there is a little significant cost variance between the Cost of DFMA Components and the Cost of DFMA Installation regarding the adoption of DfMA. This response shows both component and installation costs are quite high as regards adopting DfMA for construction works in Nigeria.

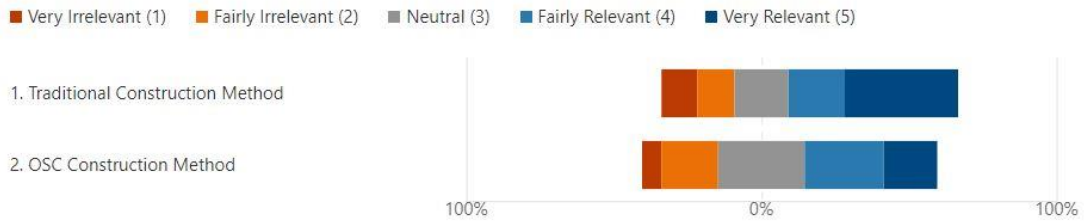

Fig. 8: Comparism of Traditional Construction Method and DfMA on Nigerian Construction Industry

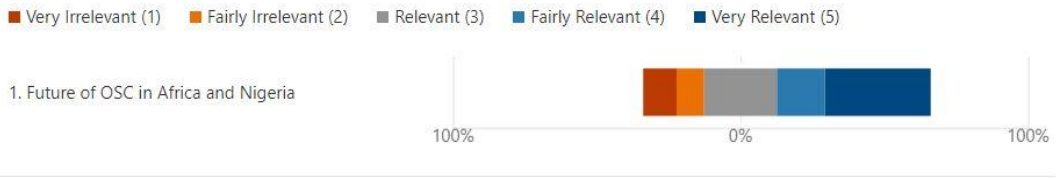

Fig. 9

While Fig. 8 shows that the Traditional Construction Method has greater relevance to today's Nigeria Construction Industry, Fig. 9 significantly reveals that the future of DfMA in Nigeria is bright.

4. CONCLUSION AND RECOMMENDATION

Off-site construction will be a way to go in the Nigerian Construction Industry in the nearest future if the barriers identified via this questionnaire and cursory research work can be addressed.

Training in universities should inculcate off-site construction and its methodology in their curricula. Marketers and producing companies should improve the supply chain management system and create more awareness among the professionals in the building industry while both the former and later co-join to relate with the government on favourable government policies through the benefits of adopting Off-site method of construction in the construction industry of Nigeria.

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