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Drivers for the implementation of modular construction systems in the AEC industry of developing countries

Abdulkabir Opeyemi Bello, Doris Omonogwu Eje, Abdullahi Idris and Mudasiru Abiodun Semiu
Department of Building, Federal University of Technology, Minna, Nigeria, and
Ayaz Ahmad Khan
University of South Australia, Adelaide, Australia

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Abstract

Purpose – The growing demand for housing and infrastructure, as well as the requirement for affordable housing, has been a significant factor, necessitating investigation for sustainable approaches and implementation of alternative construction innovations. Hence, this study aims to identify and assess the drivers for implementing modular construction systems (MCS) in developing countries.

Design/methodology/approach – The study adopts a quantitative research approach to seek respondents' opinions on the factors that can drive the implementation of MCS in developing countries. Accordingly, a structured questionnaire was used as an instrument of data collection based on five Likert scales. The data was analysed using the mean score, one sample *t*-test, Kruskal–Wallis, factor analysis (FA) and Pearson correlation analysis.

Findings – Results show that 15 of the 16 major identified drivers were statistically significant towards implementing MCS, which indicates that the drivers are crucial for implementing MCS in developing countries. However, the Kruskal–Wallis test reveals that the respondents have varying opinions on the identified drivers. FA categorised the drivers into four categories, namely, "management and sustainability", "key performance", "know-how and logistics" and "regulations and policies". A strong relationship among the four categories of drivers was established using Pearson correlation, which indicated that all the drivers' categories are essential for implementing MCS in developing countries.

Originality/value – This study identified and assessed the drivers towards implementing MCS in developing countries. The study concludes that the identified drivers are essential for implementing MCS in developing countries. Also, the study considers the government the most placed player in driving the implementation of MCS in developing countries.

Keywords Construction technique, Developing countries, Drivers, Knowledge, Government, Stakeholders

Paper type Research paper

1. Introduction

The construction industry is considered a significant contributor to every nation's economy in terms of gross domestic product (GDP). Studies have also shown the construction industry's contribution to every other sector in terms of socioeconomic development through the provision of shelter and infrastructure (Oladinrin *et al.*, 2012). As indicated by World Economic Forum (2018) construction industry contributes nearly 6% of the world GDP. Similarly, Olanrewaju *et al.* (2018) opined that the construction industry accounts for about

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5% of the world GDP, which is projected as a crucial motivator of the world economy as other sectors rely on the construction industry. Technically, the construction industry is projected to be a driving force of the nation's economy, with the potential to increase its GDP over the coming years (Bello *et al.*, 2022).

The high demand for housing and infrastructure and adequate, affordable housing has been a significant issue that motivates the need to explore sustainable methods and adopt alternative building technologies. Some of these alternative building technologies, which are being harnessed by developed countries, include lean construction, building information modelling (BIM) and industrialized building systems, also referred to as modular construction (Wuni and Shen, 2019).

Modular construction systems (MCS) is a construction method in which building components such as slabs, columns, walls and roofs are prefabricated offsite in a facility using standards and specifications and afterward transported to the site to be assembled (Lu and Korman, 2010). In a similar view, MCS comprises modules and not just components such as roof, walls and slabs but a self-enclosed volumetric unit that is prefabricated in a manufacturing plant and transported to the construction site where it is assembled while taking into consideration specification, standards and logistics (Hořínková, 2021). This innovative construction method has been widely adopted in countries such as the USA, UK, Japan, Australia, Sweden, China, Hong Kong and Malaysia due to its benefits in terms of increase in completion time, cost efficiency and sustainability (Faiz *et al.*, 2016). However, Akinradewo *et al.* (2021) opined that unless the government in developing countries lead the race to adoption and implementation of MCS by developing policies and regulation, stakeholders might not be motivated to adopt and implement MCS.

Consequently, MCS has various applications which are influenced by the type of projects, such as high-rise buildings, which include hotels, office buildings and commercial buildings of up to 25 floors, which shows the flexibility of MCS and fosters repeatability and consistency in terms of specifications (Thai *et al.*, 2020; Lawson *et al.*, 2012). Furthermore, some of these structures can integrate steel, concrete and wood structures and modules in projects (Hořínková, 2021). Some other historical examples of modular building include the Dymaxion House 1920s, the top-secret town of Oak Bridge, Tennessee, in 1942 and the 2019 Wuhan Leishenshan hospital in China (Wagner, 2022).

According to Ismail *et al.* (2022), other production industries and sectors have long adapted and implemented confined environments and mass manufacturing concepts, achieving cost, time and waste reduction levels. The construction industry globally has gradually followed suit to mitigate the drawbacks of conventional construction methods (CCMs). Despite implementing MCS in some parts of the world, this novel approach is occurring in the developed world (Akinradewo *et al.*, 2021; Wuni and Shen, 2019). Most research is linked to developed economies. Developing countries face challenges meeting the exponential population rise, necessitating more buildings to accommodate the populace. The CCMs cannot provide a rescue path. MCS has been established as a fast and efficient method of construction that will provide a lasting solution to these challenges in developing countries (Akinradewo *et al.*, 2021; Wuni and Shen, 2019). However, MCS usage has been lacking, as well as research to encourage the adoption and implementation in developing countries (Wuni *et al.*, 2019). Previous studies (Akinradewo *et al.*, 2021; Hussein and Zayed, 2021; Wuni and Shen, 2019) have recommended more studies to investigate MCS in developing countries, which could, in turn, bring about its implementation. Previous related developing countries' studies on MCS focus more on investigating the influencing barriers. As a result, this study aims to identify and assess the drivers for implementing MCS in developing countries by seeking the opinion of built environment professionals in developing countries. The findings of this study will immensely contribute to the body of existing literature and establish drivers for implementing MCS in developing countries, allowing industry and government to make informed decisions about implementing MCS in developing countries.

2. Review of related literature

2.1 Drivers towards modular construction systems in developing countries

The developed countries possess advanced technological infrastructure, making adopting and implementing new technologies such as MCS easier than developing and least developed countries with undeveloped industrial capacity. Ofori (2019) says construction in developing countries has not made much progress over the decade, despite its importance. There have not been many notable discoveries or advances in understanding. On the other hand, the developed country's construction industry has advanced technologies, equipment, machinery and qualified personnel to develop massive structures. According to Akdag and Maqsood (2019), adopting and adequately implementing new technologies is the only viable way to bridge the gap between the developing and developed construction industry.

MCS has been adopted over the decades to increase the production of buildings due to the exponential increase in population and requirements, which is beyond the capacity that can be achieved with the CCMs. Several studies on MCS have shown the benefits of significantly reducing construction time and improved productivity (Alagbe and Aina-Badejo, 2019; Qi *et al.*, 2019). However, it is argued that these benefits may require specific considerations such as choice of materials, selection of 2D panels, 3D modules or hybrid designs and proper management of design challenges, manufacturing, technology, logistics, assembly, scalability and repeatability (Bertram *et al.*, 2019). According to Hořínková (2021), the time efficiency of MCS results from restricting the production process to the interiors of a manufacturing plant, thus, increasing the production and assembly time, lowering the worker's total work time, thereby saving on wages and cost of accommodation and reducing environmental disturbances in terms of noise and vibration as well as increasing safety performance.

The low adoption of this construction method was hinged on insufficient practical knowledge and familiarity with the prefabrication technology (Wuni and Shen, 2019). In addition, MCS requires a specialised/skilled workforce, high logistic rate, non-flexibility in terms of size and weight, and the need for types of machinery for lifting and assembly on site, which stood as significant constraints to its adoption (Hussein and Zayed, 2021; Zhang *et al.*, 2018). Generally, the positive result of implementing MCS is apparent in developed countries and almost not visible in developing countries, especially African ones (Sholanke *et al.*, 2019).

MCS can significantly improve quality, standardization and cost-effectiveness due to increased production efficiency and waste minimization (Adindu *et al.*, 2020; Alagbe and Aina-Badejo, 2019; Aule *et al.*, 2018; Kayode, 2013). Implementing MCS in developing countries will enhance project completion time, thereby saving costs (Akinradewo *et al.*, 2021). The need for the government to make policies and adopt MCS practices is one of the drivers to creating acceptability and implementing this construction method (Wagner, 2022). The result of this can be linked to some developed countries (UK, USA, Hong Kong, China, Sweden and Australia). In a few developing countries (Singapore and Malaysia), the government has used MCS and established policies and subsidies to encourage the adoption and implementation of MCS.

Wuni and Shen (2019) success factors in the area of management practices for modular construction were a good working collaboration between stakeholders, standardisation, optimisation, automation and benchmarking of best practices; effective supply chain management and logistics, early design freeze and completion; and effective procurement and contracting methods. The issue of land optimisation is essential when considering return on investment, time and cost-saving solutions, land area constraints and mass housing development (Alagbe and Aina-Badejo, 2019). This method can be adopted in projects with land area constraints, landfills, swampy areas, mass housing development and high-rise buildings. It promotes standardisation, repeatability and economy of scale (Wuni and Shen, 2019). The implementation of MCS depends on certain factors related to the location (proximity to the plant) and the module's transportation costs, methods and routes (Adindu *et al.*, 2020). As most of the production process is carried out in enclosed plants using automated facilities, which reduces wet trades, MCS has another benefit over CCMs in that it is independent of unfavourable weather conditions during construction (Shin and Choi, 2022; Aule *et al.*, 2018). These factories allow for monitoring and control and also increase worker safety through relative exposures to inclement weather, temperature extremes and hazardous operations, making them suitable for emergency projects (Ayodeji *et al.*, 2016).

These factors have been highlighted from previous studies that can be analysed to ascertain the readiness and motivation for implementing MCS in developing countries, as shown in Table 1.

3. Methodology

3.1 Study methodology discussed

The scope of this research is divided into four distinct processes: a review of related literature, questionnaire design and distribution/collection, data analysis and result presentation and discussion, as shown in Figure 1. The study adopts a quantitative research approach, which allows for data to be collected numerically and subjected to statistical analysis to investigate the drivers for implementing MCS in developing countries. According to Johnson and Gill (2010), quantitative research will require a well-structured methodology to enable replication by further studies and reliability. This approach uses a questionnaire for data collection (Saunders *et al.*, 2016). A structured questionnaire was developed for this study and shared among the professionals (Architect, Builder, Engineer, Project Manager, Quantity Surveyor, Estate surveyor and Land surveyor) based on a five-point Likert-scales. Collins (2018) establishes that Likert scales are adequate for obtaining participants' opinions on different assertions. Moreover, the questionnaire can reach broader respondents from various locations within a minimal duration. This approach has been adopted in various related construction studies (Akinradewo *et al.*, 2021; Olanrewaju *et al.*, 2020).

The targeted population for the study includes built environment professionals in developing countries. Although the primary focus was on Nigeria and South Africa, other professionals within the context of developing countries are welcome to contribute to the study. This explains why Nigeria and South Africa dominated the study with 42.22% and 38.92%, respectively, totalling 81.14%. Because the architecture engineering and construction (AEC) industry contributes largely to a nation's GDP, the criteria for selecting Nigeria and South Africa were based on high GDP rate (Wikipedia, 2022).

As it may not be feasible to identify the population size, the study adopts a snowballing sampling technique that allows the respondents to recruit other professionals with similar qualities to participate. This technique has been successfully adopted in similar studies (Omopariola *et al.*, 2022; Akinradewo *et al.*, 2021) where the population size is unknown. The respondents' selection criteria are chartered professionals in particular fields of expertise. These professionals have been trained academically and practically. In addition, the professionals have the requisite related work experience to make meaningful contributions to the study.

S/No.	Major drivers	Drivers breakdown	References
1	Time efficiency	Shorter assembling duration than the conventional method, Compressed project schedules and reduced project completion time	Ismail *et al.* (2022); Hořínková (2021); Xu *et al.* (2019); Lawson *et al.* (2012)
2	Waste reduction	Maximising environmental performance during fabrication, Reducing environmental impact, Improved Waste Minimization, Reduction of Energy and Water Consumption	Ismail *et al.* (2022); Alagbe and Aina-Badejo (2019); Xu *et al.* (2019); Wuni and Shen (2019); (2018); Musa *et al.* (2018); Lawson *et al.* (2012); Lu and Korman (2010)
3	Productivity performance	Efficiency in the use of material and labour	Ismail *et al.* (2022); Musa *et al.* (2018); Peltokorpi *et al.* (2018); Jellen and Memari (2013); Arif *et al.* (2012)
4	Quality performance	The integrity of Building Design and Construction	Hořínková (2021); Alagbe and Aina-Badejo (2019); Xu *et al.* (2019); Peltokorpi *et al.* (2018); Maronati *et al.* (2018); Kayode (2013)
5	Safety performance	Reduction in site accidents	Hořínková (2021); Ogunde *et al.* (2016); Lawson *et al.* (2012)
6	Cost performance	Effective cost planning and control, cost of management, material and labour	Ismail *et al.* (2022); Musa *et al.* (2018); Ogeye (2017); Faiz *et al.* (2016); Kadhim *et al.* (2009)
7	Government	Government Usage of MCS, Policies and regulations, Government Subsidy	Wagner (2022); Aderemi *et al.* (2019); Wuni and Shen (2019); Xu *et al.* (2019)
8	Social performance	Client's demands, Higher Profitability, Accessibility to Prefabricated Materials, Decentralization of Raw Material Supply and Finished Building Material	Ismail *et al.* (2022); Bertram *et al.* (2019); Wuni and Shen (2019); Qi *et al.* (2019); Ogunde *et al.* (2016)
9	Standardisation	Elimination of site malpractices and errors	Wuni and Shen (2019); Bertram *et al.* (2019); Kayode (2013)
10	Weather	Efficient against adverse and poor weather	Shin and Choi (2022); Aule *et al.* (2018); Ogunde *et al.* (2016)
11	Good management	Good working collaboration approach, Management of Supply Chain and Logistic, risk management, Procurement Strategy and Contracting	Wuni and Shen (2019); Qi *et al.* (2019); Faiz *et al.* (2016); Kadhim *et al.* (2009)
12	Land use optimisation	Maximisation of limited land space, suitability for poor land conditions	Wuni and Shen (2019); Alagbe and Aina-Badejo (2019); Ogeye (2017)
13	Location and transportation	Plant proximity to the site, availability of adequate logistics, location of the factory, size of modules to be transported, availability of adequate vehicles to transport modules	Ismail *et al.* (2022); Adindu *et al.* (2020); Xu *et al.* (2019); Alagbe and Aina-Badejo (2019); Faiz *et al.* (2016)

(*continued*)

Table 1.
Identified drivers of MCS in developing countries

S/No.	Major drivers	Drivers breakdown	References
14	Knowledge	Training, awareness, experienced and technical workforce, skilled on-site installation and continuous improvement and learning, research and development	Wuni and Shen (2019); Qi *et al.* (2019); Ogunde *et al.* (2016), Faiz *et al.* (2016); Kayode (2013); Arif *et al.* (2012)
15	Operation	Proper planning, scheduling and guidelines, understanding the regulations, effective communication, involvement of all team members in the design and construction stage, lean construction and proper coordination	Hořínková (2021); Wuni and Shen (2019); Faiz *et al.* (2016)
16	Availability of adequate technology	Equipment and types of machinery, standardisation and manufacturing repetition, information and communication technology	Wuni and Shen (2019); Alagbe and Aina-Badejo (2019); Qi *et al.* (2019); Faiz *et al.* (2016); Kayode (2013)

Table 1.

Source: Authors Compiled Through Literature Review

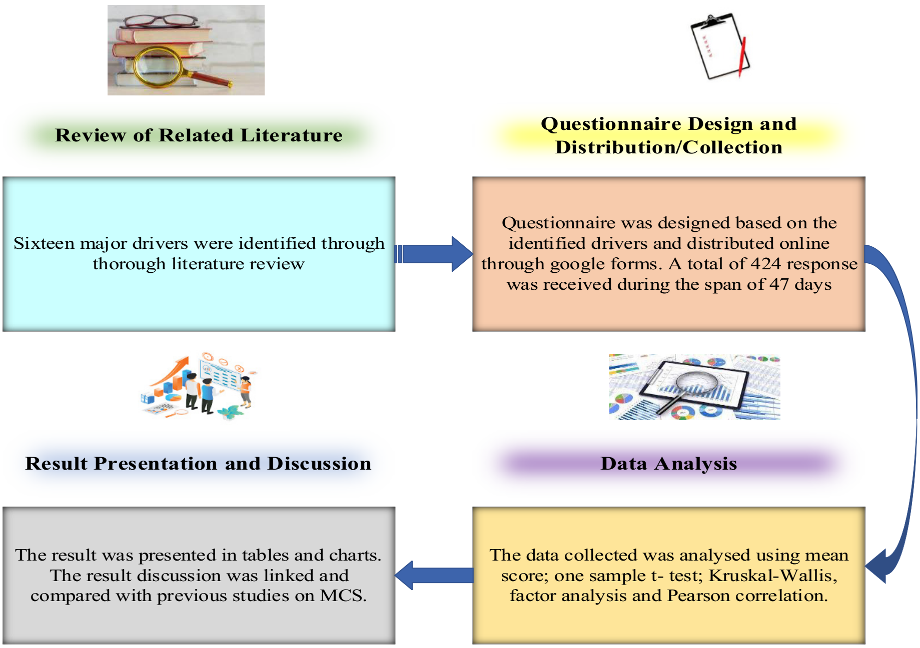


Figure 1.
Research process

Source: Authors' original creation

The structured questionnaire was distributed through electronic means (Google Forms) among the built environment professionals in developing countries. A total number of 424 responses were received from the respondents. This response rate is deemed fit for the study considering related construction studies (Okafor *et al.*, 2022; Omopariola *et al.*, 2022;

Akinradewo *et al.*, 2021; Olanrewaju *et al.*, 2020). Descriptive and inferential statistics were used to analyse the obtained data. The data were subjected to Cronbach's alpha coefficient reliability test to determine if the data was suitable and reliable for the study. It is necessary to test Cronbach's alpha coefficient for internal consistency and reliability (Maree and Pieterson, 2016). According to Maree and Pieterson (2016) rule of thumb for interpreting Cronbach's alpha coefficient, a value of 0.90 is considered highly reliable, 0.80 is considered moderately reliable and 0.70 is considered low. Consequently, the reliability output of the obtained data was (0.901), which is highly reliable, consistent and suitable for further analysis.

The collected data were analysed using Statistical Package for Social Science software and Microsoft excel. The statistical tool used was the mean score (MS), one-sample *t*-test, Kruskal–Wallis (one-way ANOVA) test, exploratory factor analysis (EFA) and Pearson correlations analysis. The MS was adopted to outline the relative rankings of the implementation of MCS from all the respondents from highest to lowest order of importance. In addition, it is necessary to investigate variation in the respondents' opinions (profession), which necessitates using the Kruskal–Wallis test to establish if there is significant variation in the opinion of more than two groups of respondents. Furthermore, EFA is adopted to reduce and group the identified drivers of MCS in developing countries into distinct categories. This statistical tool has been adopted for the same purpose in related construction studies (Akinradewo *et al.*, 2021; Olanrewaju *et al.*, 2020; Shurrab *et al.*, 2019). Finally, the relationship between the categories of the drivers was investigated using the Pearson correlations analysis.

4. Results and discussions

4.1 General characteristics of respondents

Table 2 shows the general characteristics of the respondents with a total number of 424 responses. Architects account for 18.87% of the total respondents; Builders account for the highest percentage at 28.54%; Engineers at 25.54%; Project managers at 11.08%; Quantity surveyors with 12.97% and other built environment professionals (Estate and Land surveyors) with 3.07%. Respondents with a bachelor's degree accounted for the most significant percentage at 65.09%, followed by a master's degree at 21.23%, a higher national diploma/postgraduate diploma accounts for 7.55% and finally doctorate at 6.13%.

Considering the years of related experience, 19.10% of the respondents have less than five years of working experience, 31.37% have 6–10 years of working experience, representing the highest participation, followed by 11–15 years with 25.94%, 16–20 years with 17.45% and 21 years above with accounts for the lowest participation with 6.13% level of participation. The main clients of the respondents were categorised into; private and government, with 71.23% and 28.77%, respectively.

Most respondents work in a small firm, 69.58%; medium firm, 19.81%; and large firm, 10.61%. Respondents from Nigeria account for 42.22%, South Africa 38.92% and other developing countries with 18.87% participation. Based on the characteristic of the respondents, it can be established that respondents will understand the questions and peculiarities and provide adequate responses required to assess the drivers of MCS in developing countries.

4.2 Drivers ranking and significance

Table 3 shows the ranking of the sixteen identified drivers for MCS implementation in developing countries' AEC industry. The majority (93.75%) of the identified drivers are statistically significant at ($p < 0.05$) using a one-sample *t*-test value benchmark of 3.5 value.

Respondents profile	Frequency	%
Profession		
Architect	80	18.87
Builder	121	28.54
Engineer	108	25.47
Project manager	47	11.08
Quantity surveyor	55	12.97
Other built environment professional	13	3.07
Total	*424*	*100.00*
Highest academic qualification		
HND/PGD	32	7.55
Bachelor Degree	276	65.09
Master's Degree	90	21.23
Doctorate Degree	26	6.13
Total	*424*	*100.00*
Years of experience in AEC industry		
Less than five years	81	19.10
6–10 years	133	31.37
11–15 years	110	25.94
16–20 years	74	17.45
21 years above	26	6.13
Total	*424*	*100.00*
Main client		
Government	122	28.77
Private	302	71.23
Total	*424*	*100.00*
Size of firm		
Small 0–49 employees	295	69.58
Medium 50–249 employees	84	19.81
Large 250 above employees	45	10.61
Total	*424*	*100.00*
Country of respondent		
Nigeria	179	42.22
South Africa	165	38.92
Other developing countries	80	18.87
Total	*424*	*100.00*

Source: Analysis of Authors Retrieved Data

Table 2.
Characteristics of respondents

This benchmark was adopted in the previous construction-related study (Olanrewaju *et al.*, 2020) to investigate the variable's significance. In addition, the mean score ranking of the identified drivers ranged from 4.76 to 3.55, which was above the set 3.5 threshold, indicating that all the drivers are essential for implementing MCS in developing countries.

The identified drivers, as shown in Table 3, ranged from "Knowledge" (MS = 4.76; SD = 0.542; KTS = –0.699; SKS = −0.052; t = 47.997; df = 423; Sig. = 0.000*), which is ranked highest to "Land use optimization" (MS = 3.55; SD = 0.969; KTS = –1.007; SKS = −0.017; t = 1.003; df = 423; Sig. 0.317) which is ranked lowest. Even though land use optimisation is ranked lowest and not statistically significant (p = 0.317) among the identified drivers, it still meets the set threshold (3.5), indicating it is also vital for implementing MCS in developing countries. As a result, other drivers found to be statistically significant and meet the set

Table 3. Mean score ranking for the identified drivers of MCS in developing countries

Code	Drivers	N	MS	SD	KTS	SKS	t	df	Sig. (2-tailed)	R	Significant ($P < 0.05$)
							Test value = 3.5				
DrMCS14	Knowledge	424	4.76	0.542	−0.699	−0.052	47.997	423	0.000*	1	Yes
DrMCS16	Availability of Adequate Technology	424	4.33	0.695	−1.040	0.321	24.679	423	0.000*	2	Yes
DrMCS6	Cost Performance	424	4.31	0.653	0.007	−0.427	25.451	423	0.000*	3	Yes
DrMCS7	Government	424	4.25	0.968	−0.741	−0.285	16.052	423	0.000*	4	Yes
DrMCS13	Location and Transportation	424	4.25	0.708	−0.504	−0.070	21.883	423	0.000*	5	Yes
DrMCS1	Time Efficiency	424	4.23	0.648	8.813	−2.686	23.290	423	0.000*	6	Yes
DrMCS4	Quality Performance	424	4.23	0.656	0.016	−1.000	23.033	423	0.000*	7	Yes
DrMCS5	Safety performance	424	4.03	0.733	0.487	−0.685	14.965	423	0.000*	8	Yes
DrMCS2	Waste Reduction	424	4.02	0.769	1.492	−0.979	13.902	423	0.000*	9	Yes
DrMCS3	Productivity Performance	424	3.99	0.776	1.124	−0.717	13.073	423	0.000*	10	Yes
DrMCS11	Good Management Control	424	3.97	0.730	−0.833	−0.066	13.298	423	0.000*	11	Yes
DrMCS15	Operation Efficiency	424	3.97	0.743	−1.028	0.197	12.941	423	0.000*	12	Yes
DrMCS8	Social Performance	424	3.88	0.755	−0.817	−0.160	10.480	423	0.000*	13	Yes
DrMCS9	Standardisation	424	3.87	0.795	−1.132	−0.095	9.656	423	0.000*	14	Yes
DrMCS10	Weather	424	3.75	0.840	−1.183	−0.049	6.013	423	0.000*	15	Yes
DrMCS12	Land usage optimisation	424	3.55	0.969	−1.007	−0.017	1.003	423	0.317	16	No

Notes: N: Number of respondents, MS: mean score of the identified drivers to MCS, SD: standard deviation, KTS: Kurtosis, SKS: Skewness, df: degree of freedom, Sig: significance level ($p < 0.05$ *), R: Rank. The higher the mean score, the more critical the driver
Source: Analysis of Authors Retrieved Data

threshold include "Availability of adequate technology" (MS = 4.33, p = 0.000*); "Cost Performance" (MS = 4.31, p = 0.000*); "Government" (MS = 4.25, p = 0.000*); "Location and transportation" (MS = 4.25, p = 0.000*); "Time efficiency" (MS = 4.23, p = 0.000*); "Quality performance" (MS = 4.23, p = 0.000*); "Safety performance" (MS = 4.03, p = 0.000*); "Waste performance" (MS = 4.02, p = 0.000*); "Productivity performance" (MS = 3.99, p = 0.000*); "Good management control" (MS = 3.97, p = 0.000*); "Operation efficiency" (MS = 3.97, p = 0.000*); "Social performance" (MS = 3.88, p = 0.000*); "Standardisation" (MS = 3.87, p = 0.000*); and "Weather" (MS = 3.75, p = 0.000*). Consequently, all the identified drivers are essential for implementing MCS in developing countries. The identified drivers must be considered simultaneously to achieve optimum implementation results. Considering a section of the drivers during implementation processes will result in a failed process. Previous researchers have studied the factors influencing MCS in the AEC industry. Wuni and Shen (2019) and Arif *et al.*(2012) established that the propeller for the adoption of innovations is tied to the level of available knowledge, which is lacking in the construction industry as relates to MCS. Knowledge-acquiring platforms such as training and re-training, seminars and research can critically impact the ease of adoption and implementation of MCS (Wuni and Shen, 2019; Arif *et al.*, 2012). MCS is characterised by advanced technology and equipment that can significantly drive its implementation. MCS is driven by the availability of adequate technologies capable of enhancing prediction accuracy and repetitions, plants and types of equipment (Alagbe and Aina-Badejo, 2019). Cost performance is a significant determinant of MCS implementation; its implication can have a positive or negative impact depending on how it is managed. This factor can arise from proper or improper management of plants and equipment, poor workmanship, materials wastage and poor weather (Musa *et al.*, 2018; Ogeye, 2017). Faiz *et al.* (2016) established that effective cost planning and management are necessary for MCS implementation. However, due to the method of MCS operation, it edges against poor weather, reduces poor workmanship, increases quality and limit rework on site and reduces waste to the minimal, which is one of the significant challenges ravaging the AEC industry. Achieving all these will bring about cost optimisation for both clients and the contractor. Similarly, MCS requires a higher initial investment cost (Ismail *et al.*, 2022). Due to requirements for higher initial investment costs, small and medium-sized organisations will find it challenging to enter MCS businesses. Developing policies and codes by the governments for implementing MCS is essential to drive its adoption and implementation in developing countries rapidly. In contrast to other developed countries such as the USA, UK, Australia, Sweden, China and Hong Kong, where the government has stepped into adopting and implementing MCS, it has seen positive results in the respective countries. Singapore and Malaysia are a few developing countries experiencing adoption and implementation through government support. However, this is lacking in African countries, mainly developing and least developing countries. Wagner (2022) affirms that government usage and policies on MCS are a rapid driver that can bring about general acceptability and adoption of this innovation. Similarly, support from the government regarding guidance, innovation and implementation such as policies, regulations, licenses, subsidies and approval is key to its acceptability and popularity in any economy (Wuni and Shen, 2019; Xu *et al.*, 2019).

Implementation of MCS depends on certain factors related to the location (proximity to the factory) and the module's transportation costs, methods and routes (Adindu *et al.*, 2020; Faiz *et al.*, 2016). Studies by Ismail *et al.* (2022), Xu *et al.* (2019) and Alagbe and Aina-Badejo (2019) have also established the significance of good location and transportation considerations towards implementing MCS. Although land use optimisation is not statistically significant in this study, it is established to be essential for implementing MCS in developing countries. Previous studies (Wuni and Shen, 2019; Alagbe and Aina-Badejo, 2019; Ogeye, 2017) have all established this factor as a critical driver of MCS. As reported by (Ismail *et al.*, 2022; Hořínková, 2021; Musa *et al.*, 2018; Lawson *et al.*, 2012), time and operation efficiency, productivity, quality, social and safety performance and waste reduction established these factors have major motivators to implement MCS. Similarly, (Shin and Choi, 2022; Wuni and Shen, 2019; Ogunde *et al.*, 2016) established reasonable management control, standardisation and weather also form significant drivers of the adoption of MCS. Consequently, all the study-identified drivers are important towards the implementation of MCS in developing countries and must be used simultaneously for optimum results.

4.3 Kruskal–Wallis one way ANOVA

Table 4 shows the Kruskal–Wallis test adopted to assess the significant difference in opinions among the various respondents (profession) using a significance level of $p < 0.05$. This approach has been adopted in previous construction-related studies (Omopariola *et al.*, 2022; Akinradewo *et al.*, 2021). Table 4 shows that there is a significant difference ($p < 0.05$) in opinion among 68.78% of the 16 identified drivers of MCS in developing countries. Consequently, the professionals have similar opinions 31.22% on other drivers. This outcome is similar to Akinradewo *et al.* (2021), where the respondents have different and similar opinions on the variables identified.

4.4 Exploratory factor analysis

Table 5 shows the Kaiser–Meyer–Olkin (KMO) and Bartlett test of sphericity (BTS) rotated component matrix, variance and cumulative percentage for the identified variables. In further analysis, data adequacy was investigated using the KMO and BTS, as shown in Table 5. According to Field (2013) and Hair *et al.* (2010), the KMO value can vary between 0 and 1 and recommended 0.5 as the minimum score for further tests. The BTS is used to investigate the strength of the relationship between the identified variables (Field, 2013).

Code	Drivers	K–S	Chi-Square	df	K–W	df	Asymp. Sig.	Remarks
DrMCS1	Time Efficiency	0.000[c]	304.358[a]	3	10.219	5	0.069	Rejected
DrMCS2	Waste Reduction	0.000[c]	158.623[a]	3	19.574	5	0.002*	Accepted
DrMCS3	Productivity Performance	0.000[c]	152.736[a]	3	29.363	5	0.000*	Accepted
DrMCS4	Quality Performance	0.000[c]	98.693[b]	2	17.309	5	0.004*	Accepted
DrMCS5	Safety performance	0.000[c]	194.509[a]	3	11.813	5	0.037*	Accepted
DrMCS6	Cost Performance	0.000[c]	490.127[c]	4	9.500	5	0.091	Rejected
DrMCS7	Government	0.000[c]	422.132[c]	4	15.765	5	0.008*	Accepted
DrMCS8	Social Performance	0.000[c]	332.958[c]	4	16.461	5	0.006*	Accepted
DrMCS9	Standardisation	0.000[c]	293.146[c]	4	39.634	5	0.000*	Accepted
DrMCS10	Weather	0.000[c]	140.509[a]	3	20.763	5	0.001*	Accepted
DrMCS11	Good Management Control	0.000[c]	196.509[a]	3	33.373	5	0.000*	Accepted
DrMCS12	Land usage optimisation	0.000[c]	141.660[a]	3	42.853	5	0.000*	Accepted
DrMCS13	Location and Transportation	0.000[c]	416.849[c]	4	8.522	5	0.130	Rejected
DrMCS14	Knowledge	0.000[c]	1020.953[c]	4	1.339	5	0.931	Rejected
DrMCS15	Operation Efficiency	0.000[c]	179.849[a]	3	34.485	5	0.000*	Accepted
DrMCS16	Availability of Adequate Technology	0.000[c]	467.132[c]	4	7.473	5	0.188	Rejected

Notes: K–W: Kruskal–Wallis, K–S: Kolmogorov–Smirnov; $p < 0.05$; Significance (Asymp. Sig.): less than 0.05*
Source: Analysis of authors retrieved data

Table 4. Kruskal–Wallis one-way ANOVA test result

Table 5. Factor analysis results for the identified drivers

Code	Identified drivers to MCS	Component 1	2	3	4	Classification	% of Variance	Cumulative %
DrMCS11	Good Management Control	0.779				*Management and Sustainability*	29.827	29.827
DrMCS10	Weather	0.765						
DrMCS8	Social Performance	0.750						
DrMCS12	Land usage optimisation	0.726						
DrMCS9	Standardisation	0.683						
DrMCS15	Operation Efficiency	0.650						
DrMCS3	Productivity Performance	0.582						
DrMCS2	Waste Reduction	0.523						
DrMCS1	Time Efficiency		0.677			*Key Performance*	17.04	46.866
DrMCS4	Quality Performance		0.662					
DrMCS6	Cost Performance		0.646					
DrMCS5	Safety performance		0.594					
DrMCS14	Knowledge			0.831		*Know-how and Logistics*	14.27	61.136
DrMCS16	Availability of Adequate Technology			0.703				
DrMCS13	Location and Transportation			0.667				
DrMCS7	Government				−0.861	*Regulations and Policies*	9.24	70.376
Kaiser–Meyer–Olkin Measure of Sampling Adequacy								
Bartlett's Test of Sphericity				Approx. Chi-Square			4,079.564	
	df						120	
	Sig						0.000	

Notes: Extraction method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. a. Rotation converged in 13 iterations
Source: Analysis of authors retrieved data

The analysis output shows a KMO value of 0.949, indicating good adequacy. BTS was significant at 0.000*, considering a significance level of ($p < 0.05$), as shown in Table 5.

Table 5 shows the result of the rotated component matrix, variance and cumulative percentage for the identified variables, adopting a criterion for retaining variables of 0.50 benchmark for loading of factor and eigenvalue of 1.0 as opined by Hair (2010). All the variables are retained after loading. Figure 2 shows the decision criterion of the Scree plot result, which was determined sufficiently suitable to draw out the number of variables in this study. Factor analysis (FA) was conducted following the adequacy of data for further analysis; principal component analysis extraction and the varimax rotation method with Kaiser normalization were used to perform FA. Categories of the four retrieved drivers from the FA had a combined variation of 70.376% from the 16 indicated drivers, above Pallant's (2007) threshold of 50%. Each category of extraction is discussed below.

4.4.1 Management and sustainability. Category one (good management control, weather, social performance, land usage optimisation, standardisation, operation efficiency, productivity performance and waste reduction) accounts for 50% of the total identified drivers with a loading factor of 0.779, 0.765, 0.750, 0.726, 0.683, 0.650, 0.582 and 0.523, respectively, and varimax percentage of 29.827%. Management and sustainability are closely linked and play a crucial role in the success of MCS.

Good management control is essential for ensuring that construction projects are completed on time and within budget. This is particularly important in MCS, where prefabricated components are manufactured offsite and assembled on-site. By having a well-managed construction process, it is possible to ensure that the components are manufactured to a high standard and fit together correctly on-site. This helps to reduce waste and improve the overall quality of the finished building. Waste reduction is an important consideration in MCS, as it helps minimize the project's environmental impact and reduce costs. Achieving adequate operation methods also helps to reduce costs and waste

Land usage optimization is crucial in MCS, as it allows for the efficient use of limited land resources in developing countries. For instance, MCS can be used to build multi-story buildings on a smaller piece of land, which can help to alleviate the pressure on urban areas. In addition, components can be manufactured in bulk, reducing costs and increasing

Source: Analysis of authors' retrieved data

Figure 2. Scree plot for the identified drivers

efficiency, bringing about increased standardization. Weather can also have a significant impact on modular construction projects. Adequate planning and management can help to mitigate the effects of bad weather and ensure that projects are completed on schedule. These factors must be carefully considered and managed to ensure that projects are completed on time, within budget and with minimal environmental impact.

4.4.2 Key performance. Category two (time, quality, cost and safety) accounts for 25% of the total identified drivers with loading factors of 0.677, 0.662, 0.646 and 0.594, respectively, and a varimax percentage of 17.04%. Drivers identified under this category are critical considerations and determinants towards transitioning from CCMs to MCS. Usually, clients are more concerned with the expended cost, completion time and quality of the project; this has usually been the traditional method of measuring project performance. However, cost, time and quality can be seriously affected and jeopardised if there are safety lapses. Using prefabricated components can help reduce the risk of accidents and injuries on construction sites. Additionally, using standardized components can make it easier to ensure that structures are built to meet safety standards.

In developing countries with high housing and infrastructure demand, the time-efficient characteristic of MCS can be advantageous. Moreso, the use of prefabricated components can ensure a high level of quality control and consistency in the finished product. In addition, the use of standardized components can make it easier to maintain and repair facilities over time. Furthermore, in developing countries, using prefabricated components can help reduce the cost of construction by making it possible to develop buildings faster and more efficiently. Generally, the key performance factors of time, quality, cost and safety are important drivers for implementing MCS in developing countries.

4.4.3 Know-how and logistics. Category three (knowledge, availability of adequate technology, location and transportation) accounts for 18.75% of the total identified drivers with loading factors of 0.831, 0.703 and 0.667, respectively, and a varimax percentage of 14.27%. Generally, innovations such as MCS requires a skilled and competent workforce to drive its adoption and implementation effectively; these can range from proper designing, planning, fabrication of modules, handling of plants and equipment, installations, supervision and inspections and logistics handling. Usually, developing countries lack good roads, ranging from the poor state of roads and linkages to small widths to accommodate large vehicles and modules during transportation. In addition, the roads are sometimes not designed to withstand heavy loads from transporting large modules. These challenges can be mitigated by providing adequate roads to accommodate large vehicles and modules and building manufacturing plants in strategic locations to enhance delivery. Furthermore, know-how is required for designing and fabricating modules that meet local building codes and regulations, as well as for the management of MCS sites. Consequently, logistics is essential for transporting modules from the manufacturer to the construction site and coordinating assembly and installation. Without the proper know-how and logistics, MCS can be a difficult and costly operation.

4.4.4 Regulations and policies. This category accounts for 6.25% of the total identified drivers, with a loading factor of –0.861 and a varimax percentage of 9.24%. Government intervention is a profound way to adopt and implement innovations. Government can drive MCS with various approaches by adopting and usage in governmental projects. Also, developing guidelines for design and building codes, labour laws and environmental standards, these regulations and policies can either support or inhibit the use of MCS. The real-life of this construction technique has been witnessed in various developed countries such as the UK, USA, China, Hong Kong, Australia and Sweden, and a few developing countries such as Singapore and Malaysia. Introducing this governmental approach to implementing MCS in developing countries can pave the way and lead to MCS implementation.

With adequate legislation and policies, it can incentivize builders and developers to use MCS, such as tax discounts or faster approval processes. This can make MCS more cost-effective and efficient, leading to wider implementation. As a result, if regulations and policies are unfavourable to MCS, it may impose additional expenses or make compliance with building codes and standards problematic. This will make MCS less appealing to builders and developers, resulting in lower adoption. Summarily, regulations and policies can drive MCS in developing countries by creating an enabling environment for acceptance and implementation.

4.5 Pearson correlations analysis

Table 6 shows the relationship between the categories of the identified drivers to MCS in developing countries. The values represent the correlation coefficient (r) between each pair of the categories in Table 6. The coefficient runs from –1 to 1, with –1 indicating a perfect negative correlation, 0 indicating no association and 1 indicating a perfect positive correlation.

The correlation coefficient among the driver categories ranges from 0.644 to –0.896, indicating appreciable relationships among the drivers. Similarly, the driver categories are statistically significant to each other. This approach was adopted in the previous study of Olanrewaju *et al.* (2020) to investigate the relationship between variables. As indicated in Table 6, all the drivers are interrelated, and the utilisation towards implementing MCS should be simultaneous. Therefore, a good result would not be achieved if a section of the identified drivers were considered in the implementation process of MCS developing countries. This result further indicated that implementation processes must consider all the drivers simultaneously for optimum results – a related study made a similar conclusion (Blismas and Wakefield, 2009).

5. Conclusion and implications

5.1 Conclusion

MCS can deliver rapid infrastructural development in developing economies if the barriers to its adoption and implementation can be overcome by implementing the drivers identified in this study. This innovative construction technique uses building components such as slabs, columns, finished walls and roofs to be manufactured offsite in a plant according to standards and specifications. Then transported to the construction site to be erected increases efficiency in project execution. This innovative approach has been widely adopted in nations such as the USA, UK, Japan, Australia, Sweden, China, Hong Kong, Singapore and Malaysia due to its numerous benefits. However, the MCS construction method increases engineering complexity, which is lacking in developing countries and poses a critical barrier to implementing MCS in developing countries, leading to low MCS projects in developing countries.

Drivers	Management and sustainability	Key performance	Employee and logistics	Regulations and policies
Management and Sustainability	1			
Key Performance	0.794**	1		
	0.000			
Employee and Logistics	0.644**	0.730**	1	
	0.000	0.000		
Regulations and Policies	–0.697**	–0.713**	–0.896	1
	0.000	0.000	0.753	

Notes: **Correlation is significant at the 0.05 level (two-tailed)
Source: Analysis of authors retrieved data

Table 6. Pearson correlations analysis

Despite the adoption of MCS in some parts of the world, as observed in the developed world, the opposite is true in developing nations, especially in Africa. The developing countries struggle to keep up with the exponential population's growth, necessitating the construction of more buildings to shelter the ever-expanding populations and activities. This issue motivated this study to identify and assess the drivers for the deployment of MCS in developing nations. All identified drivers except "land usage optimization" were statistically significant. Based on the mean score, 93.75% of the identified drivers, ranging from knowledge to weather, were statistically significant. The top-ranked drivers are knowledge, followed by adequate technology availability, cost performance, government, location and transportation. The professionals have varying opinions on the drivers for implementing MCS in developing countries. However, most professionals have similar opinions on the identified drivers.

This study categorised these drivers into "management and sustainability", "key performance", "know-how and logistics" and "regulations and policies". Furthermore, a strong relationship is established among the identified drivers indicating that all the drivers are crucial. Therefore, these drivers must be considered simultaneously towards implementing MCS in developing countries.

Consequently, this study outcome contributes to the existing scientific knowledge as a resource for academic environments and the industry, which may be used as a template to adequately approach MCS implementation in developing countries. Implementing MCS adequately in a country's construction industry will increase productivity, which has been a significant challenge in the construction industry over the past decades. Similarly, this novel approach to construction will bring about an increase in the nation's GDP and increase the number of skilled operatives. The construction industry's GDP is envisioned to increase in the coming years due to the adoption and implementation of new technologies that aid construction operations throughout the project's lifecycle, such as lean construction, the Internet of Things, BIM, Blockchain and Digital Twin.

Moreso, there is a need for attitudinal change to increase flexibility and operability among the construction industry stakeholders to transition from the CCMs to MCS to foster the implementation of MCS. Knowledge-acquiring platforms, notably higher institutions, have a more significant role in this process by providing adequate MCS training to construction-related students. This approach will serve as a grassroots strategy for creating MCS awareness and increasing implementation. Similarly, various departments could tailor and re-tailored the syllabus to provide adequate MCS training (theory and practical). In addition, the various professional bodies should provide adequate training to the professionals and make MCS courses a prerequisite to becoming a chartered professional. Finally, governments should be the front runner in implementing MCS due to its capabilities to handle large projects and develop policies, codes, regulations and monitoring guides for the implementation. Also, initiate a subsidy plan to encourage other stakeholders to implement MCS in developing countries. This study's findings and conclusions are congruent with the available MCS literature.

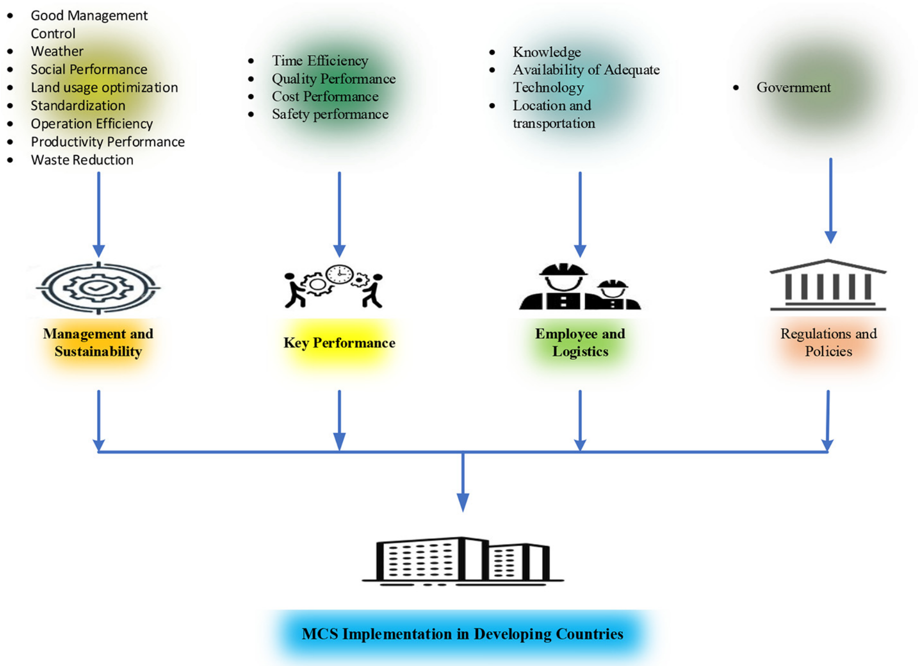
5.2 Implications of the study

Literature has investigated the influence of MCS implementation in different countries. However, most of these studies are carried out in developed countries, which has helped better implement MCS. On the other hand, studies in the context of developing countries are lacking, especially in investigating the drivers that can motivate the implementation of MCS in developing countries, which this study has been able to satisfy. This study gathers responses from a wide range of professionals across different locations. Although the significant participating professionals are from Nigeria and South Africa, other professionals from developing countries are accommodated to contribute to the study, making the study unique, rich and a reliable reference source. The findings of this study will aid the industry stakeholders when considering the implementation of MCS in developing countries.

Furthermore, the outcome of this study can stimulate and positively change the negative public attitude towards implementing MCS. Therefore, academia and researchers will immensely benefit from this study as it provides a reliable and comprehensive outcome to aid teachings and future study directions. Notably, the government and policymakers will benefit from the outcome of this study to develop sustainable and well-informed policies for implementing MCS in developing countries. Summarily, if used, this study will provide adequate directions and significantly contribute towards implementing MCS in developing countries and the least developing countries. Figure 3 shows the developed model for MCS implementation based on the study result.

This study has limitations, such as the number of professionals and countries polled and the available time for research. Future research can consider the following:

- Examine additional developing nations, especially outside of Africa and more professionals.
- Adopt other methodological approaches and methods of analysis (multi-criteria decision methods).
- Develop a conceptual framework and implementation strategies for MCS in developing countries.
- Carry out empirical studies on factors affecting the implementation of MCS.



Source: Authors' original creation

Figure 3.
MCS implementation model

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Corresponding author
Abdulkabir Opeyemi Bello can be contacted at: abdulkabiropeyemi@gmail.com