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Application of artificial intelligence in the Nigerian building and construction industry

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ABSTRACT

The uniqueness and inherent complexities of the construction industry require the use of Artificial Intelligence (AI) to improve its processes and enhance overall competitiveness and performance. This study examined the awareness level and application of AI to provide useful insights into the state of AI applications in the Nigerian construction industry. A quantitative research design with the use of a questionnaire was used to obtain data from 53 construction professionals in the Lagos Island area of Lagos State, Nigeria. The professionals included Quantity Surveyors, Architects, Civil Engineers, Builders, and Estate Surveyors selected based on a purposive sampling technique. Data from the survey were analyzed with frequencies, mean, and ANOVA. The study found that most of the respondents were aware of the application of AI in construction, and there was no difference in the awareness level of the participants irrespective of their professional affiliations, organizational type, and organizational size. Generally, the most common application of AI among the participants surveyed were generative designs in BIM, measurement and estimating software, and the use of sensors in intelligent buildings. Moreover, design and project planning was found to be the most critical areas of need for AI in the study area. The study underscores the need for investments in other AI applications other than BIM and estimating software to improve productivity, performance, and enhance client satisfaction.

1. Introduction

AI is the ability of a machine to mimic human behavior intelligently through the use of algorithms to solve difficult problems (Salehi and Burgueño, 2018). One of the main objectives of AI is to train machines to reason, plan, process, perceive, move and manipulate things like humans, with a view to solving complex organizational or day-to-day challenges (Adio-Moses and Asaolu, 2016; Chen et al., 2012). AI consists of intelligent systems that use structured or unstructured data, to learn and imitate human behavior thereby making informed decisions (Boileau, 2019). Summarily, AI is the generation of human-like intelligence that can learn, reason, plan, perceive, or process natural language in order to collate and organize information for use in an organization, or to perform a routine human task.

The application of AI is growing because of its ability to provide solutions in uncertain and complex situations. It has the potential to tackle problems, which overwhelm the human mind in terms of complexity or volume of data (Eber, 2020). It also creates convenience, improves productivity, and adds value to a system (Güngör, 2020). AI has wide applicability in all sectors, and it has been found to produce positive outcomes for social, environmental, and economic sustainability (Vinuesa et al., 2020).

AI is also well suited for the construction industry because of the uniqueness and inherent complexities of the industry. For instance, projects in the industry are one-off, construction products are immobile, multiple stakeholders and regulatory agencies are involved, and work packages are fragmented. These features of the industry make the management of projects difficult and almost overwhelming to the

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human mind, and this limits the performance of the industry. The literature is replete with performance issues in the construction industry including cost overruns (Durdyev, 2021), time overruns (Johnson and Babu, 2020), safety concerns (Tunji-Olayeni et al., 2019a), litigation (Hayati et al., 2017), waste generation (Luangcharoenrat et al., 2019), and environmental pollution (Tunji-Olayeni et al., 2019b). Rivera et al. (2016) noted that many projects worldwide still experience delays, cost overruns, rework, and low customer satisfaction, which negatively affect the performance of the construction industry globally. The use of AI in the building and construction industry can enhance the efficiency of construction processes (Salehi and Burgueño, 2018; Afolabi et al., 2020), and reduce waste and safety concerns (Froese, 2010). It can also improve the planning, design, monitoring process, and maintenance of construction facilities (Allam and Dhunny, 2019), thereby enhancing the overall performance and competitiveness of the industry.

Some studies on the application of AI in the construction industry have been done in the past. For instance, Hsu et al. (2018) developed a model for optimizing the manufacturing, storage, and assembly logistics in modular construction. Khobragade et al. (2018) used Artificial Neural Network (ANN) algorithm to predict housing rates for improving the planning, construction, and sales of buildings. Poh et al. (2018) used machine learning to develop indicators that can classify construction sites according to their safety levels. Mohan and Varghese (2019) used AI to improve safety on construction sites. Delgado et al. (2019) assessed the factors that limit the adoption of robots and automated systems in the construction industry. Schia et al. (2019) assessed the application of AI and its impact on human behavior. Yaseen et al. (2020) adopted AI to predict a delay in construction projects. Ajayi et al. (2020) adopted text mining to develop deep learning models for health and safety management in power projects. Egwim et al. (2021) used ensemble algorithms to improve the predictive capability of single algorithms in predicting construction project delay. Other works on AI in the construction sector were reviews such as Abioye et al. (2021), Eber (2020), Prieto (2019), Parveen (2018), Mosly (2017), Martínez and Fernández-Rodríguez (2015), and Lu et al. (2012).

In spite of the value-adding potentials of AI as revealed in past studies, its application in the construction industry globally is still limited (Boileau, 2019). Lack of awareness and misconception of the concept of AI has been identified as one of the limitations to its use, especially in the construction industry (Prieto, 2019). For instance, PEGA (2017) noted that only one-third of the people who come in contact with AI realize that they are actually using it. Hence, understanding the awareness level and current applications of AI will provide useful insights into the state of AI applications in the building and construction industry.

On awareness of artificial intelligence, Basaif et al. (2020) assessed the awareness level of AI application for risk analysis among construction practitioners in Malaysia. The study was however focused on the awareness of AI in analyzing only risk in construction projects. In the case of AI studies in the Nigerian construction industry, Adio-Moses and Asaolu (2016) assessed the systems that enhance the use of AI in the Nigerian construction industry. The study was based on a single case study of the Eko-Atlantic project in Lagos, Nigeria. Although the study attempted to assess the systems that enhance the use of AI such as nanotechnology, building information modeling (BIM), and Lean Construction, the level of AI awareness and the specific applications of AI in the Nigerian building and construction industry were not examined.

Hence, this paper sets out to fill this gap by assessing the awareness level, current use, and critical areas where artificial intelligence is needed in the Nigerian building and construction industry.

By providing empirical evidence of the awareness level, current use, and critical areas of need, this study offers some major contributions to the theory and practice of AI in the building and construction industry globally and in Nigeria in particular. The study also provides baseline data that can inform policies that will promote the application of AI and also encourage AI investments in the Nigerian construction industry.

2. Methodology

In this paper, a survey research design with questionnaires was used to obtain data from 53 construction professionals through a purposive sampling technique. The study was based in the Lagos Island area of Lagos State, Nigeria. The study participants consisted of Architects, Builders, Civil Engineers, Quantity Surveyors, and Estate Surveyors working in consulting firms, contracting firms, clients' organizations, and government agencies.

The study was carried out between January and March 2021. Questionnaires were distributed electronically with the use of google forms sent to the WhatsApp numbers and email addresses of the participants.

The questionnaire had four sections. Section one consisted of the demographic profile of respondents such as profession, organizational type, organizational size, and respondents' level in the organization. Section two focused on the awareness of the application of AI in the building and construction industry. Questions in section two were presented on a 5-point Likert scale from-Very Aware (5)/Aware/Not Sure/Slightly Aware/Not Aware (1). The third section sought to identify the current application of AI in the Nigerian Building and Construction industry. Section four had questions that centered on the critical areas of need for AI in the Nigerian construction industry. The items in the fourth section were also rated on a 5-point Likert

scale from–Most Critical (5)/Critical/Not Sure/Slightly Critical/Not Critical (1).

Cronbach's alpha test was used to determine the reliability of the items used to assess the critical need areas for AI in the Nigerian construction industry. An alpha score of 0.798 (Table 1) was obtained, indicating a good measure of internal consistency within the items in the questionnaire (Tavakol and Dennick, 2011).

Table 1: Reliability analysis

Cronbach's Alpha	Number of Items
0.798	11

Data from the survey were analyzed using descriptive statistics such as frequency, mean analysis, percentages, and standard deviation. Inferential statistics including ANOVA were also used in analyzing the data.

In determining respondents' awareness level of the application and critical area of need for AI in the Nigerian construction industry, a mean range, obtained from the mean analysis, was used for the categorization. The categorization is shown below:

$5.00 \geq x \geq 4.50 = very\ aware/\ most\ critical$
$4.49 \geq x \geq 3.50 = aware/\ critical$
$3.49 \geq x \geq 3.00 = slightly\ aware/slightly\ critical$
$2.99 \geq x \geq 1.00 = not\ aware/\ not\ critical$

3. Discussion of findings

3.1. Profile of the respondents

The profiles of the respondents are presented in Table 2. With regards to respondents' professions, 5.7% were Architects, 26.40% were Builders, 15.1% were Engineers, 39.6% were Quantity Surveyors, and 13.2% were Estate/Facility Managers. Table 2 also shows that 24.5% worked with consulting firms, 41.5% worked with contracting firms, 22.6% worked with client organizations and 11.4% worked with government agencies. Table 2 also indicates that 7.5% of the respondents were lower-level management staff, 34% were middle-level management staff, 39.6% were senior-level management staff and 18.9% were executive-level management. In terms of organizations' size, 22.6% had below 10 persons in their organization, 35.8% had below 50 persons in their organization, 18.9% had between 51 and 250 persons in their organizations while 22.6% had more than 250 persons in their organization.

Table 2: Respondents' demographic details

Demographic detail		Frequency	Percent
Profession	Architect	3	5.7
	Builder	14	26.4
	Engineer	8	15.1
	Quantity surveyor	21	39.6
	Estate/Facility manager	7	13.2
	Total	53	100
Organization	Consulting firm	13	24.5
	Contracting firm	22	41.5
	Client organization	12	22.6
	Government agency	6	11.4
	Total	53	100
Management level	Lower-level management	4	7.5
	Middle-level management	18	34
	Senior-level management	21	39.6
	Executive-level management	10	18.9
	Total	53	100
Staff strength (Organizational size)	Below 10 persons	12	22.6
	Below 50 persons	19	35.8
	51-250 persons	10	18.9
	More than 250 persons	12	22.6
	Total	53	100

3.2. Awareness of the application of artificial intelligence in the Nigerian building and construction industry

The study assessed the awareness of the application of artificial intelligence in the Nigerian building and construction industry. Table 3 shows the awareness level of artificial intelligence by profession and by organization type. From Table 2, the overall mean score for awareness level by profession was 3.60. This mean score is within the range of 4.49 ≥ x ≥ 3.50, indicating that the professionals were aware of the application of artificial intelligence.

This result is similar to findings on other digital technologies. For instance (Akinradewo et al., 2021) found that professionals in the South African construction industry were aware of the use of robotics and construction automation. Contrarily, construction professionals in Malaysia have a low awareness of the use of AI for construction risk analysis (Basaif et al., 2020).

Mean scores for the level of awareness of architects, builders, engineers, quantity surveyors, estate/facility managers were 3.33, 4.00, 3.88, 3.33, and 3.43 respectively. The mean scores for architects, quantity surveyors, and estate/facility managers lie within the range of 3.49 ≥ x ≥ 3.00,

indicating that architects, quantity surveyors, and estate/facility managers were slightly aware of the use of artificial intelligence in the Nigerian building and construction industry. However, Builders and Engineers had mean scores of 4.00, and 3.88 which is between the range of 4.49 ≥ x ≥ 3.50, indicating that they were more aware of the application of artificial intelligence than the other professionals in the Nigerian building and construction industry.

With regards to the awareness level of the application of artificial intelligence by organizational type, Table 3 shows that the overall mean was 3.60. This mean score lies within the range of 4.49 ≥ x ≥ 3.50, indicating that all the organizational types surveyed were aware of the application of artificial intelligence in the construction industry. Among all the organizational types surveyed, client organizations were most aware of the application of artificial intelligence in the Nigerian construction industry with a mean score of 4.00, which lies between 4.49 ≥ x ≥ 3.50 while consulting firms and government agencies were the least aware, with mean scores of 3.38, and 3.00 respectively. These mean scores were within the range of 3.49 ≥ x ≥ 3.00. of the use of artificial intelligence in the Nigerian construction industry. Since client organizations were most aware of the application of intelligence in the Nigerian construction industry, a further analysis was done to assess the professionals in the client organization, the results (Table 4) show that builders were the most common professions in the client organization. These results further collaborate with the finding in Table 3, that builders were most aware of the application of artificial intelligence in the Nigerian construction industry.

Furthermore, the study examined statistical differences in the awareness level across the profession, organization type, and organization size (Table 5). The results show that there was no statistical difference with respect to the profession, organization type, and organization size.

Table 3: Awareness of the application of AI in the Nigerian Construction industry

Variable	Mean	SD	Decision
Profession			
Architect	3.33	1.155	Somewhat aware
Builder	4.00	0.961	Aware
Engineer	3.88	1.126	Aware
Quantity surveyor	3.33	0.966	Somewhat aware
Estate/Facility manager	3.43	0.976	Somewhat aware
Overall	3.60	1.007	Aware
organization			
Consulting Firm	3.38	1.121	Somewhat aware
Contracting Firm	3.64	1.002	Aware
Client organization	4.00	0.739	Aware
Government agency	3.00	1.225	Somewhat aware
Overall	3.60	1.015	Aware

SD: standard deviation

Table 4: Cross tabulation organization profession

		Profession					Total
		Architect	Builder	Engineer	Quantity surveyor	Estate/Facility manager	
Organization	Consulting firm	0	1	1	8	3	13
	Contracting firm	2	7	6	7	0	22
	Client organization	1	4	0	4	3	12
	Government agency	0	2	1	2	0	5
Total		3	14	8	21	6	52

Table 5: ANOVA for awareness of the application of artificial intelligence in the Nigerian construction industry

Awareness	F	p-value
By profession	1.191	0.327
By organization type	1.445	0.241
By organization size	0.165	0.920

The study further analyzed the various tools and tasks for which artificial intelligence is applied in the Nigerian construction industry. Table 6 shows the common applications of artificial intelligence in the Nigerian construction industry. The most common applications of artificial intelligence from the survey were generative design in BIM and other software, measurement and estimating, and sensors for intelligent buildings.

Table 6 further shows that the use of wearable sensors, 3D printing, and drones for surveying sites and buildings were the least applied. Moreover, the most common artificial intelligence application/task used by architects is generative design in BIM and other software, builders mainly used artificial intelligence for sensors for intelligent buildings, engineers made use of artificial intelligence for drones for monitoring construction activities, and sensors for intelligent buildings, quantity surveyors used artificial intelligence for measurement and estimating, while estate/facility managers use artificial intelligence in sensors for scheduling planned maintenance and for identifying structural issues (Table 6).

The study also assessed the critical tasks that require the application of artificial intelligence in the Nigerian construction industry (Table 7). The three most critical tasks are design (4.46), planning project

(4.39), and estimating project time (4.39). Table 7 also shows partially replacing labor and supervising projects as the least critical tasks for the application of artificial intelligence in the Nigerian construction industry.

Table 6: Application of artificial intelligence in the Nigerian construction industry

		Profession					Total
		Arch.	Bldr.	Engr.	QS	Est/Fac Magr.	
AI application	Generative Design in BIM or other Software	3	3	1	3	0	10
	Measurement and Estimating	0	0	0	8	0	8
	Sensors for intelligent buildings	0	5	2	0	0	7
	Drones for monitoring construction activities	0	2	2	0	0	4
	Sensors for scheduling planned maintenance	0	0	0	0	3	3
	Sensors for identifying structural issues	0	0	0	0	3	3
	Drones for viewing restricted areas	0	1	0	2	0	3
	Sensors for monitoring safety on site	0	1	0	0	0	1
	Drones for surveying sites and buildings	0	1	0	0	0	1
	3D Printing	0	0	1	0	0	1
	Wearable sensors for site workers	0	0	0	0	0	0
Total		3	13	6	13	6	41

Arch: Architect; Bldr: Builder; Engr: Engineer; QS: Quantity surveyor; Est/Fac Magr: Facility manager

Table 7: Critical tasks for AI Applications

Task	Mean	Std. Deviation
Design	4.46	0.646
Planning project	4.39	0.777
Estimating project time	4.39	0.606
Monitoring site safety	4.37	0.599
Identifying risk	4.34	0.717
Estimating project cost	4.28	0.671
Supervising projects	4.22	0.737
Partially replacing labor	3.66	0.717

4. Implications of the findings

There is a general awareness of the application of AI in the Nigerian construction industry, irrespective of professional affiliation, organizational type, and organizational size. In terms of the awareness of professionals about the application of AI, builders were more aware than any other professional in the construction industry. Builders engage in more practical construction than any other professional on-site. They are more in touch with the complexities and challenges of construction. They may be more inclined or open to solutions for improving the building process including the use of AI. This may explain why builders are more aware of the use of AI than any other professional in the Nigerian construction industry. With regards to specific AI applications, BIM and estimating soft wares were the most common. Providing different design options for clients to select from within budget constraints may be a major challenge for the industry in today's dynamic world. Hence, the application of AI-enabled BIM generative designs and estimating software to optimize designs and improve cost performance seems to be more common in the Nigerian construction industry.

One of the challenges facing the industry is the high incidence of fatalities and accidents. However, the study findings indicate that there is a low application of the use of AI (sensors) in monitoring site safety. This implies that the Nigerian construction industry is yet to leverage the use of AI to minimize the occurrence of accidents. The use of drones and safety sensors should be encouraged to improve the safety profile of the industry. Moreover, the use of wearable sensors for site workers needs to gain wide application in order to minimize occupational hazards common on construction sites and among the aging workforce.

Design and project planning are seen as critical areas for the application of AI in the Nigerian construction industry. The application of artificial intelligence can enhance the design process and bring about optimized design for value engineering which will ultimately reduce construction costs, yet achieve the intended value. Project planning involves the planning of materials, machines, and men. Efficient project planning reduces waste, which improves project cost performance. This implies that design and project planning is perceived as very critical stages in the construction process which can leverage AI to enhance overall project success.

Lastly, AI technologies such as robots that can totally or partially replace labor are not seen as critical in the Nigerian construction industry. Hence, such technologies may not be able to penetrate the market at the moment.

5. Conclusion

The study examined the awareness, and application of AI in the Nigerian construction industry, based on the value-adding potential of AI to improve construction cost, time, and safety. The study participants were aware of the application of AI and there is some evidence of specific applications of AI in the Nigerian construction industry. However, the use of AI needs to gain wider application in the Nigerian construction industry. Stakeholders also need to invest in other AI applications other than BIM and estimating software. The use of AI can be a tool for market differentiation, and a source of competitive advantage, for construction professionals because of its ability to improve performance, productivity, and enhance client satisfaction. Although this work provides some empirical evidence of the awareness and application of AI in the Nigerian construction industry, the findings of the study are based on the perceptions of construction professionals in the Lagos Island area of Lagos state, Nigeria. Future studies could consider

examining the views of construction professionals from other parts of the country. Comparative studies on the application of AI in the construction industry between the global south and developed countries could also be carried out.

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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