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RETHINKING CONSTRUCTION 4.0 ADOPTION IN NIGERIA: OUTSOURCING AND INSOURCING FOR SUSTAINABILITY IN THE CONSTRUCTION INDUSTRY

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Abstract

The awareness and skills required to implement Construction 4.0, as well as its adoption, are still very low. This study aims at encouraging the insourcing and outsourcing of construction 4.0 technologies for sustainability within the Nigerian construction industry. The sampling technique used for this study was the Purposive sampling technique, Questionnaire was the Primary tool for data collection, while mean, and rank order were used to analyze the data collected. The findings show that the construction-specific construction 4.0 technologies are; LIDAR, and Building Information Modeling(BIM). While the non-construction-specific construction 4.0 technologies are; Big data, Unmanned aerial vehicles, etc. Among the various factors militating against the adoption of Construction 4.0 adoption are; the high cost of acceptance, anddata security issues. The technologies to be insourced are; LIDAR, and BIM, while those to be outsourced are; Big data, Artificial intelligence, etc. Insourcing and outsourcing can help in enhancing sustainability in the construction industry by; helping bridge the skill gap and resolve cyber security issues etc. The study developed a framework for insourcing and outsourcing construction 4.0 within the construction industry and recommends that Construction companies should be adequately sensitized on the benefits of adoptinga new approach to technology adoption.

Keywords

Insourcing, Outsourcing, Construction 4.0 Technology, Sustainability, Adoption

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1. Introduction

Alaloul *et al.* (2018) traced the history of the industrial revolution from the end of the 18th century which was the first industrial revolution that marked the first mechanical loom in 1784;it birthed the water and steam-powered manufacturing facilities. The second industrial revolution which began at the start of the 20th century (first production line, Cincinnati slaughterhouses 1870) birthed electrically powered mass production based on the division of labour. The third industrial revolution started in the 1970s (first programmable controller, Modicon 084, 1969) which used electronics and Information Technology to achieve further automation of manufacturing. While the fourth industrial revolution introduced the use of Cyber-Physical Systems. According to Xu *et al.* (2018); the First industrial revolution was between 1760-1900, with transition periods between 1860-1900, the energy resource was coal and the main technical achievement was the steam engine, the means of transportation was trainand the target industry where textile and steel. The second industrial revolution was between 1900-1960, with a transition period from 1940-1960, the energy resource was oil and electricityand the main technical achievement was the internal combustion engine, the means of transportation were train and car, and the target industries were Metallurgy, Auto, Machine Building. While the third industrial revolution was between 1960-2000, with a transition periodbetween 1980-2000, the energy resources were nuclear energy and natural gas, the main technical achievements were computers and Robots, while the means of transportation were cars and planes, and the target industries were Auto and Chemical. The Fourth industrial revolution was from 2000, with a transition period between 2000-2010, the main energy resource is green energies, and the main technical achievements are; the internet,3D printer, andgenetic engineering, and the transportation means are; electric cars, ultra-fast train, and the target industry are high tech industries.

Industrial revolution 4.0 provides the framework for the Construction industry 4.0 (i.e. Construction 4.0). Construction 4.0 is referred to as the representation of industry 4.0 in construction which makes use of ubiquitous technologies for making decisions in real-time (El Jazzar *et al.*, 2021). Forcael *et al*. (2020) identified the pillars of construction 4.0 to include; the digitalization of the construction industry and the industrialization of construction processes. Various technologies make up construction 4.0 which when adopted can improve the productivity, efficiency, and sustainability of the industry. It also enables smart movement and data revolution needed for the achievement of the united nation's goal of sustainability. But despite the benefits that adopting these technologies provides for the industry, its adoption is still very low in the construction industry compared to other sectors such as manufacturing and banking (Osusanmi et al,2018). Therefore, this study aims at encouraging the insourcing and outsourcing of construction 4.0 technologies to facilitate the adoption of construction 4.0, and to encourage sustainability in the Nigerian construction industry based on the following objectives; a) To classify the various construction 4.0 technologies into construction-specific and non- construction-specific technologies b) To identify factors militating against the adoption of Construction 4.0 adoption, c)To identify the various construction 4.0 technologies that can be insourced and outsourced d) To identify how Insourcing and outsourcing of construction 4.0 can help facilitate construction 4.0 adoption and enhance sustainability in the construction industry e) To develop a framework for outsourcing and insourcing construction 4.0 technologies in the Nigerian construction industry. Various studies have been carried out on Construction 4.0 and its technologies such as those by; Lekan *et al.* (2021) which examined the disruptive adaptationsof Construction 4.0 and Industry 4.0, Sherratt *et al*. (2020) examined Construction 4.0 and its potential impact on people working in the Construction industry, While Begic and Galic (2021)reviewed Construction 4.0in the context of the BIM premise. But, no study has been carried outon Outsourcing and Insourcing Construction 4.0 technologies for sustainability (especially in Nigeria), hence the need for this study.

2 Theoretical Framework

Agency Theory: it is used to illustrate a delegation of responsibilities from one party to another.It is created when a person (the principal) gives authority to another person (the agent) to act on his behalf (Linder and Foss, 2013); (Nnamseh, *et al.*,2020). This can be related to the study in that, non-construction-specific construction 4.0 technologies that the industry has not adopted can be outsourced outside the construction industry to enhance adoption and sustainability.

Resource-Based Theory: A firm's competitive advantage lies in the resources they possess internally (Nnamseh, *et al.*,2020). Therefore, this theory relates to the study in that construction companies have adopted different construction-specific construction 4.0 technologies, so insourcing within the industry for such competencies and skills will be of great advantage in enhancing adoption and sustainability.

2.1 Construction 4.0 and the Classification of its Technologies

Construction 4.0 is the integration of industry 4.0 into the construction industry (Mansour, *et al.*, 2021). Industrial revolution 4.0 provides the framework for construction 4.0, and some of the technologies which make up industrial revolution 4.0 include; computer-aided design and manufacturing (CAD/CAM), Big data, Additive manufacturing, simulations, and digital automation with sensors (Dalenogare, *et al.*, 2018). According to Kozlovska *et al*. (2021), some of these technologies also make up the Construction 4.0 technologies such as the internet of things, 3D printing, Big data, Augmented, virtual, and mixed reality, robotics, unmanned aerial vehicles, cloud computing, mobiles devices, Artificial intelligence, simulationsof virtual models, sensors and actuators, etc. Furthermore, there are a few of these technologies which are unique to the construction industry such as; Building Information Modeling, 3D Scanner (LIDAR), Modular and Prefabrication technology, etc. Consequently, those technologies which are common to both industry 4.0 and Construction 4.0 can be referred to as Non-Construction specific technologies, while those that are unique to the construction industry can be referred to as Construction specific technologies.

2,2Factors Militating against the Adoption of Construction 4.0

Various challenges hinder the adoption of construction 4.0 in the construction industry and various researchers have itemized them in their studies. Among the various factors which militate against the adoption of construction 4.0 are;

a) Low technical know-how (Osusanmi, *et al.,* 2018)

b) Cost acceptance of Technology and Lack of Knowledge **(**Mohd, *et al.*,2019**)**

c) Data security, data protection, and, high implementation costs (Sawhney, *et al.*,2020)

d) Challenges of fluctuating power supply, Dynamics of hackers, and cyber fraud (Lekan, *et al.*,2021)

e) Resistance to change, unclear benefits, and gains (Demirkesen & Tezel, 2021).

f) Technological risk aversion, fragmented nature of the industry (Koc, *et al.*,2020)

g) Hiring skilled people with the required expertise, Heavy lay-offs (Singh & Misra,2021)

h) Lack of awareness and lack of required skills (Adepoju & Aigbavboa,2020).

2.3Outsourcing and Insourcing Construction 4.0 Technologies for Sustainability

Enabling technologies of sustainable development include the Internet of Things, Big data, Cyber-physical systems, Cloud computing, (Ahad, *et al*.,2020), etc. These technologies make up the Construction 4.0 technologies. Adepoju and Aigbavboa (2020) observed that some of these technologies are already in use such as Building Information Modeling (BIM), and Prefabrication, while Robotics and Green building has low implementation. Furthermore, there is a willingness by construction professionals to adopt construction 4.0 technologies, hence the need to insource where the technology

is construction specific and being used within the industry because of the prevalence of knowledge/know-how among construction professionals. And outsource those technologies that aren't construction specific since their knowledge can be gotten outside the industry.

Outsourcing is the engagement of the services of specialized service providers to deliver predefined services(Meyer,2022). It gives a chance for specific skills to be gotten, lowers cost and management of risk (Dinu, 2015). Furthermore, Amusan *et al. (*2022) identified the areas of application of outsourcing concepts in Construction firms to include; Human resources, Training of human resources and the management of construction sites. While Insourcing is the production of a product or the performance of services by the in-house resource (Meyer,2022). It helps in cost reduction, dealing with quality, and control issues (Luhtala, 2021).Collectively, both outsourcing and insourcing can help with the challenges of cyber security threats, resources optimization, cost reduction, and capacity issues (both short and long-term goals). Furthermore, they both help in process expansion, enhancement, and economization, aswell as increasing revenue(Taveras,2015). The technologies that makeup construction 4.0 are both specific and non-specific to the construction industry, therefore if the adoption rate must be enhanced there is a need for an in-house collaboration between construction companies and collaboration between construction companies and other non-construction companies.

3.Research Methodology

The study adopted the use of a survey research design**,** the study surveyed three constructionsites and two works departments of a tertiary institution in Ota, Ogun state. A Population of 57

respondents comprised of professionals such as Architects, Builders, Quantity surveyors, CivilEngineers, Mechanical and Electrical Engineers, etc. Both Primary and, Secondary methods of data collection were used for this study. A quantitative approach was adopted using structured questionnaires (which was the primary data collection tool), Published articles, Journals, textbooks, etc.made up the secondary sources, of the data collection instrument. The sampling technique usedwas the purposive sampling technique because respondents had the requisite experience and were also the primary actors (who could tell the actual state of knowledge). A sample size of 50 was used for the study, which was determined through the use of the taro Yamane formula

$(n = N/ 1+ N(e)^2)$, Where N is the population of the study, and e is the sampling error. The datawere analyzed by mean score, rank order, frequency, tabulation, and percentages. Also, a Likertscale of 1-5 was used for this study, where 1 is Strongly Disagree, 2 is Disagree, 3 is Undecided,4 is Agree, 5 is Strongly Agree)

4. Results

4. 1 Profession of respondent

Table 1 Profession of respondent

S/N	PROFESSION	NUMBER OF RESPONDENTS	PERCENTAGE
1	Architect	15	30%
2	Builder	9	18%
3	Structural Engineer	4	8%
4	Quantity Surveyor	10	20%
5	Mechanical Engineer	5	10%
6	Electrical Engineer	7	14%
	TOTAL	**50**	**100**

Source: Research Survey (2023)

From Table 1, it can be seen that the profession of the respondents are; Architects with a percentage of 30%, Quantity surveyors with a percentage of 20%, Builders with a percentage of 18%, Electrical engineers with a percentage of 14%, Mechanical engineers with a percentageof 10% and Structural engineers with a percentage of 8%

4.2. Years of experience of respondents

Table 2 Years of the Respondents

S/N	YEARS OF EXPERIENCE	NUMBER OF RESPONDENTS	PERCENTAGE
1	2-10 YEARS	10	20%
2	10-20 Years	35	70%
3	20-35 Years	5	10%
	TOTAL	**50**	**100**

Source: Research Survey (2023)

From Table 2, it can be observed that respondents are mainly between 10-20 years with a percentage of 70%, those between 2-10 years with a percentage of 20%, and those between 20-35 years with a percentage of 10%.

4. 3 Construction-Specific and Non-Construction-Specific Construction 4.0 Technologies

Table 3 Construction-Specific and Non-Construction-Specific Construction 4.0 Technologies

S/N	Construction-Specific	MEAN SCORE	RANK
1	3D Scanner(LIDAR)	3.46	3
2	Modularization and Prefabrication	4.52	2
3	Building Information Modeling(BIM)	4.60	1
S/N	**Non-construction-specific technologies.**	**MEAN SCORE**	**RANK**
1	Internet of things	4.8	1
2	3D printing	4.7	2
3	Big data	4.26	3
4	Mobiles devices	4.22	4
5	Unmanned aerial vehicles	4.22	4

Source: Research Survey (2023)

Table 3 shows that respondents agree that the Construction specific technologies are; Building Information Modeling(BIM) with a mean of 4.60, Modularization and Prefabrication with a mean of 4.52, and 3D Scanner(LIDAR) with a mean of 3.46 While the Non-construction specific technologies are; Internet of things with a mean of 4.8, 3D printing with a mean of 4.7,Big data with a mean of 4.26, Mobiles devices mean of 4.22, and Unmanned aerial vehicles with a mean score of 4.22.

4. 4 Factors militating against the Adoption of Construction 4.0

Table 4 Factors militating against the Adoption of Construction 4.0

S/N	Factors militating against the adoption of Construction 4.0	MEAN SCORE	RANK
1	Lack of knowledge and Low technical know-how	4.38	2
2	Lack of Awareness	3.26	5
3	Cost of technology acceptance andhigh cost of Implementation.	4.4	1
4	Resistance to change and Heavy layOff	3.58	4
5	Data security, Protection issues	4.04	3

Source: Research Survey (2023)

Table 4 shows that respondents agree that the factors militating against the adoption of construction 4.0 adoption are; Cost of technology acceptance and the high cost of Implementation with a mean of 4.4, Lack of knowledge and Low technical know-how with a mean of 4.38, Data security, Protection issues with a mean of 4.04, Resistance to change and Heavy lay off with a mean of 3.58, and Lack of Awareness with a mean of 3.26.

4.5 Construction 4.0 Technologies to be Insourced and Outsourced

Table 5 Construction 4.0 Technologies to be Insourced and Outsourced

S/N	Construction 4.0 Technology	MEAN SCORE	RANK
1	**Insourced Technologies**		
	LIDAR	3.66	3
	Building Information Modeling	4.50	1
	Modular and Prefabrication	4.46	2
2	**Outsourced Technologies**		
	Internet of things	3.68	5
	Big data	4.48	1
	Augmented, Virtual, Mixed Reality	4.26	3
	Cloud computing	4.18	4
	Artificial intelligence	4.34	2

Source: Research Survey (2023)

Table 5 shows that respondents agree that the various technologies to be insourced are; Building Information Modeling with a mean of 4.50, Modularization and Prefabrication technology witha mean of 4.46, and LIDAR with a mean of 3.66.

4. 6 Benefits of Insourcing and Outsourcing Construction 4.0 Technologies

Table 4.6 Benefits of Insourcing and Outsourcing Construction 4.0 Technologies

S/N	**Benefits of Insourcing and Outsourcing of Construction 4.0 technologies.**	**MEAN SCORE**	**RANK**
1	Increase in revenue and resource optimization.	3.26	5
2	Dealing with capacity issues (i.e. bridging the skill gap and technical know-how)	4.50	1
3	Reduction in the Cost associated withthe technology adoption.	4.38	2
4	Expansion, enhancement, and economization of Process.	3.46	4
5	Resolving Cyber security threats.	4.22	3

Source: Research Survey (2023)

Table 6 shows that respondents agree that Insourcing and Outsourcing of Construction 4.0 technologies can facilitate construction 4.0 adoption and enhance sustainability in the construction industry by; Dealing with capacity issues with a mean of 4.50, Reduction in the cost associated with the technology adoption with a mean of 4.38, Resolving cyber security threats with a mean of 4.22, Expansion, enhancement, and economization of Process with a mean of 3.46, Increase in revenue and resource optimization with a mean of 3.26.

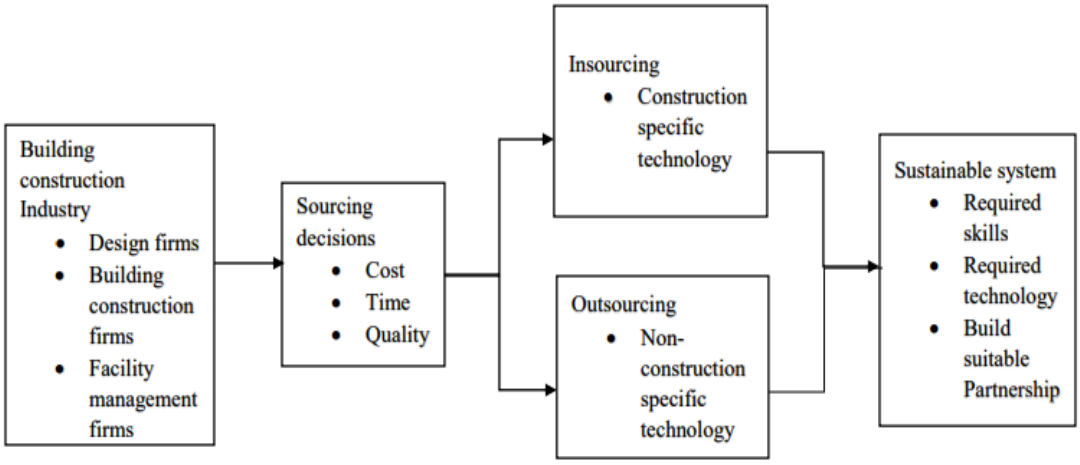

Fig 1 Proposed Framework for outsourcing and insourcing Construction 4.0 Technologies

The need to insource and outsource Construction 4.0 technologies in the Building Construction industry should be holistic, that is should involve companies in all phases of Construction such asdesign firms, construction firms, and facility management firms. This will help enable sourcing decisions.

Sourcing decisions for Construction 4.0 should be focused on the three parameters of project success such as cost (which includes cost acceptance of technology, cost of implementation), time(which includes the

time it takes to acquire the relevant technology and skills), and quality (the quality of output desired). This will help to determine whether to insource or outsource.

To decide whether to Insource and Outsource Construction 4.0 technologies, Constructioncompanies should decide which construction 4.0 technologies to insource and outsource (i.e. Construction specific technologies and Non-Construction specific technologies) as this will help the industry in acquiring the relevant skill and technologies, and in the long-run in achieving a project goal of cost and time reduction, and quality improvement. This will help enable a sustainable system.
To achieve a sustainable system, the right technology, the right skills, and suitable partnershipshould be built.

4. Discussion

The various construction 4.0 technologies can be classified into construction-specific such as BIM, Modular and Prefabrication technology, and LIDAR, while the non-construction-specifictechnologies are; Internet of things, 3D printing, Big data, mobile devices, and Unmanned aerialvehicles. This agrees with Ngowi *et al.* (2005) which stated that one form of industrialization (i.e. of construction) is Prefabrication, which is the industrial manufacture of building components off or near the site. While Doan *et al.* (2019) stated that BIM is a fusion of CAD, information management, and collaboration, which spans various building delivery workflowssuch as architectural, electrical structural, etc. Halili, (2019) in his study identified the various industrial revolution technologies such as; Artificial intelligence, the Internet of things, and bigdata relevant for students in the workplace. While Lazim *et al.* (2020) in their study adopted theuse of these technologies such as the Internet of Things, autonomous robot, big data analytics, and artificial intelligence in the Agricultural sector.

The Factors militating against the adoption of Construction 4.0 are; Lack of knowledge and Low technical know-how, Lack of Awareness, cost of technology acceptance and high cost of implementation, resistance to change and heavy layoff, data security, and Protection issues. This agrees with Zhi *et al.* (2022). which identified lack of technical skill and knowledge, lackof manpower, lack of awareness, etc. as major barriers to the adoption of Industrial revolution in the Malaysian construction industry. Ibrahim et al. (2022) identified the hindrances to the adoption of Industrial revolution 4.0 by construction consultants are; the cost of adopting the technologies, cost of adopting the technologies.

The various construction 4.0 technologies that can be insourced are; LIDAR, Building Information Modeling, and Modular and Prefabrication. This agrees with Chang, *et al.* (2018) which state that for building prefabrication to succeed in china, there was a need for job site training and apprenticeship. While those to be outsourced are; the Internet of things, Big data, Augmented, Virtual, Mixed Reality, Cloud computing, and Artificial intelligence. This agrees with Chang-Richards *et al.* (2022). which state that there is a need to outsource technical skillssuch as machine learning, deep learning, etc. as a stand-alone disciplinary approach will not behelpful in creating the necessary talent pool needed in the industry. The study emphasized the need for a balance between depending on a third party and incubating home-grown solutions by recruiting/upskilling.

The Benefits of Insourcing and Outsourcing of Construction 4.0 technologies are; Increase in revenue and resource optimization, increase in revenue and resource optimization, dealing withcapacity issues, Reduction in the Cost associated with the technology adoption, expansion, enhancement, and economization of process, and resolving cyber security threats. This agrees with Chang-Richards *et al*. (2022) which state that collaboration, partnership, third-party engagement, recruiting, and up-skilling can help change the culture and mindset of employees at all levels, develop technical skills, and provision of critical talent capabilities in the construction industry and help to facilitate successful technology adoption/implementation.

5. Conclusions

The advent of the Industrial revolution provided the framework for Construction4.0, hence thetechnologies that make up Construction 4.0 are a mixture of both Industrial revolution technologies and those of the construction industry

such as Modularization and Prefabrication technology, Building Information Modeling (which are both Construction-specific technologies), while technologies such as The internet of things, Cloud Computing, Artificial Intelligence are the Non-Construction specific technologies. The adoption of these technologiesin the Construction industry has been hindered by several factors among which include; Lack of knowledge and Low technical know-how, Lack of Awareness, cost of technology acceptance and high cost of implementation, resistance to change, and heavy layoff, data security, and Protection issues. Therefore, the need to outsource some of those technologies which are not unique to the construction industry such as the internet of things, Artificial intelligence, and insource those technologies which are unique to the construction industry such as BIM, Prefabrication technology, to facilitate the quick adoption of these technologies and enhance sustainability in the Construction industry. A framework was developed in the study that could in the quick adoption of Construction 4.0 technologies in the Nigerian construction industry. This study is limited to the Construction industry (especially in Nigeria) experiencing a slow adoption rate of technology. To this end, the study recommends that Construction companies should collaborate within themselves and with othernon-construction companies to hasten the adoption of these construction 4.0 technologies, Government should provide a regulatory framework for insourcing and outsourcing activities between companies and within the country, the right professionals with the requisite skill shouldbe placed in the right position, so as encourage the insourcing strategy, Construction companiesand Professionals should be adequately sensitized on the benefits of adopting a new approach to technology adoption, Training and development should be encouraged by construction companies, in order to acquire and sharpen skills. Further studies can be carried out in other Construction industries around the world with other analytical methods. This study contributes to knowledge in that it will help encourage a faster and better way to hasten the adoption of Construction 4.0 and provide a quick way in which Construction companies can bridge the skill and technology gap associated with Construction 4.0 through outsourcing and insourcing. Thereby, fostering innovation, building resilient infrastructure, and enabling sustainable development

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