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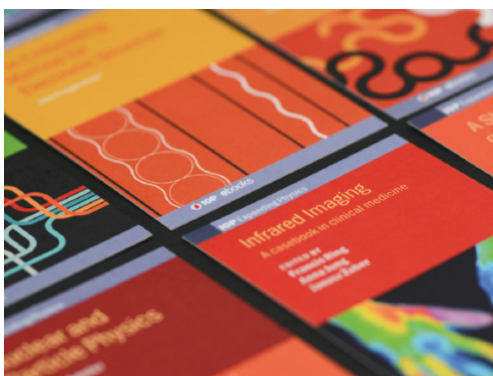
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Assessment of the role of Lean Construction Practices in Environmental Sustainability

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Abstract: The Construction Industry of which the building industry is a subsidiary has been identified as an industry that can help in the achievement of environmental sustainability. Literature has established practices such as Virtual Design and Construction (VDC), Prefabrication and Modularization and Just-in-Time (JIT) and others as environmental sustainable LCPs. Therefore, this paper investigated the adoption of these practices and areas LCPs adoption can help contribute to environmental sustainability in the Nigerian Building Industry. In order to achieve the aim of the study, a questionnaire survey was conducted in Abuja, Lagos, Port-Harcourt, Enugu and Kaduna covering five out of the six geo-political zones of Nigeria. The sample frame for the study consisted of architectural, building consulting and contracting and quantity survey firms in the selected cities. Totally, 446 valid responses were collected and analyzed descriptively using the Statistical Package for Social Sciences (SPSS). The results from the study revealed that firms in the Nigerian building industry have adopted all the 32 investigated LCPs. Specifically, it was found that VDC was the most adopted of all the 32 LCPs investigated in the Nigerian building industry. In addition, the result reveals that respondents are of the opinion that adoption of LCPs in building can help in the achievement of a sustainable environment through massive reduction of construction wastes that are injurious to the ecosystem.

Keywords: Lean Construction Practices; Environmental Sustainability; Virtual Design and Construction, Prefabrication and Modularization; Just-In-Time

1. Introduction

The construction procurement process involves many activities, including the extraction of raw materials; actual construction and demolition of unserviceable buildings and fixed infrastructure. As a result of this, this industry is known to consume enormous resources and also produces all kinds of physical and non physical wastes that contribute to negating the ongoing efforts toward achieving sustainable development [1]. Consequently, efforts to increase the level of sustainability of the construction industry and its subsidiaries such as the building industry have seen the application of lean construction for the delivery of construction projects [2]. According to [3], lean construction has the potential to eliminate wastes and improve customer (value), which invariably enhances the sustainability of the construction industry [4]. This is because one of the cardinal objectives of sustainability is to eliminate wastes and improve value for money [5]. Value in this context encompasses social, economic and environmental benefits associated with the delivery of built projects to the client and end users [3]. This explains the nexus between lean construction and



sustainability as both have mutual influence over the other. Notably, whereas lean construction is designed to make projects sustainable, achieving sustainability in building projects delivery is possible by making the projects leaner [5].

From the foregoing, it could be seen that a relationship exist between lean construction and sustainability; meaning that the construction industry has a role to play in the attainment of the sustainability goal. In fact, studies have shown that lean construction can be applied to achieve sustainability in different areas and dimensions [6, 7]. In spite of this, there is insufficient evidence in the research literature to establish the adoption of LCPs in the Nigerian construction industry. As a result, it has been difficult to understand the role lean construction plays in promoting environmental sustainability in Nigeria. Therefore, this research aimed at filling in this gap by investigating the adoption of the 32 LCPs practices identified in the systematic review of literature by [8]. The specific objectives are: to assess the extent of adoption of LCPs in the Nigerian building industry; and to examine stakeholders' perspectives on the environmental sustainability benefits of lean construction practices. Based on these objectives, the emphasis is on the identification of the level of adoption of those practices that have great potentials in helping to achieve environmental sustainability in Nigeria. The study is based on the perspective of stakeholders in the Nigerian building industry and their perceived environmental benefits associated with the adoption of LCPs in the procurement of projects. The study contributes to knowledge by revealing the proportion of stakeholders in the Nigeria building industry that has adopted the different lean tools and improving understanding of their opinions on the potential benefits of these practices in promoting environmental sustainability.

2. Nexus between lean construction and sustainability

This section establishes the relationship between lean construction and sustainability as identified from the literature. Studies have explored the specific areas of link between lean construction and environmental sustainability [9, 10]. According to [9], these areas include resource management, waste reduction, energy minimization, elimination of non-value added process and health and safety improvement. Particularly waste reduction and health and safety improvement have been identified as the two most important areas [5]. According to [7], health and safety practices contribute to sustainability in construction by enhancing workers' social life and minimizing direct and indirect cost resulting from accidents. In addition, material waste elimination promotes the most efficient and cost effective approach to sustainable building practices in the construction industry thereby achieving a sustainable environment [7].

Meanwhile, [7] have also explained that, lean construction applications may affect different dimensions of sustainability. For instance, [6] revealed that lean construction practices provide more economic impacts than the social and environmental impacts. Yet, [5] identified the social, economic and environmental dimensions of sustainability in lean construction at the operational level of project delivery. The emerging consensus in the research literature suggests that socially, lean construction promotes the commitment of construction operators to sustainability and continuous improvements. Economically, construction workers can own the planning process, which serves as a motivation to efficient use resources. Environmentally, lean construction practices promote the use of resource, materials and techniques efficiently [8]. For the three dimensions, the connection between lean construction and sustainability emphasises value for money – which is an integration of the social, economic and environmental benefits associated with the procurement and use of the different kinds of buildings. Khodeir and Othman [3] have argued the link between lean construction and sustainability should be considered at the same time the concepts should be applied concurrently to yield more benefits especially for the environment.

Fliedner [11] has identified some lean practices that could help achieve environmental benefits. Such practices include 5s, Kaizen and Value Stream Mapping (VSM) which helps to identify and eliminate hidden wastes in the process and products, pull scheduling, which also helps in lowering waste from deterioration and damages of products before and after process via inventory taking. In addition, Total Preventive Maintenance (TPM) helps to achieve environment sustainability by increasing the life span of equipment used for production through maintenance as they are used. Furthermore, TPM helps to reduce the need for part replacement that causes spills, leaks and upset of the environment through pollution. In the same vein, lean practices such as Six Sigma is very useful in achieving reduction of defects during production, resources and energy use up, while plan for condition of work and environment enables proper planning before design, with consideration to material use and environment of the work. Again previous research [8] emphasised that practices such as modularization and prefabrication, Visual Design and Construction (VDC) tools and Just-in-time supports the achievement of environmental sustainability by enabling the efficient use of resources, and by so doing contribution to a massive reduction of material waste generation and promoting green construction. It can be inferred from the foregoing that lean construction plays a key role in environmental sustainability by encouraging the efficient use of resources and eliminating waste in the procurement and use of buildings.

In view of the established link between lean construction and sustainability goal, adoption of lean construction practices should be considered a key approach for the delivery of sustainable buildings leading to increased sustainability in the construction industry [2]. Many of these practices such as Kanban, kaizen and last planner are very useful [9] for visualizing, streamlining and benchmarking the construction process for increased sustainability. However, it should be known that when lean practices are applied over the lifecycle of a built product, they contribute to sustainability differently. It is also important to take cognisance of the findings by [10] revealing that the commonly used lean tools and techniques such as kaizen are only useful in a very limited number of phases in the building lifecycle. While those that span most phases include practices such as JIT and are closely associated with the specified sustainability objectives in building and other construction projects. Nonetheless, [8] were able to categorise 32 lean practices that support different phases of the construction process, thereby exposing LCPs practices that could aid the achievement of sustainability at each phases. This implies that a generic application of lean construction tools and techniques may not necessarily lead to the achievement sustainability in the construction industry, but adoption the right mix of practices would produce the desired result.

3. Research Methods

The data used in this article is part of the data derived in a larger research work that was designed to evaluate the diffusion and adoption of lean practices (LPs) in the Nigerian building industry. The research design was a survey and the data used are mainly quantitative in nature. The survey was conducted through the administration of structured questionnaire to architecture, building consulting and contracting, and quantity surveying firms in Abuja, Lagos, Port-Harcourt, Enugu and Kaduna drawn from five geopolitical zones of Nigerian excluding the Northeast zone, where there are obvious security challenges. The cities were selected because they had the highest concentrations of firms in the building industry in each zone in Nigeria.

The population of the study consisted of all the consulting and contracting firms operating in the Nigerian building industry. While 1116 registered, firms in the aforementioned cities constituted the sample frame for the study; this was drawn out of the lists of such firms provided by [12, 13 and 14]. However the sample size for this study was calculated to be 446 firms. This was determined using Leslie Fisher's formula:

$$(n = Z^2 P (1-P) / d^2) \quad (1)$$

This was multiplied by an adjustment factor of non-response given as

$$(q = 1 / (1-f)) \quad (2)$$

Where “Z” was 1.96 at a confidence level of 95%, “P” proportion of sample characteristics of interest being 50% and error of sampling being 0.05. This resulted in a minimum value of 404 firms, however to make the sample size distribution systematic 40% from each category of firms was estimated and then used as the sample size for this study.

A multi-stage sampling approach was also used in the selection of participants in the survey. This involved the use of cluster-sampling method for identification of existing clusters of firms within the selected cities and then, random sampling was adopted for both selection of the firms within the clusters and selection of participant to represent the selected firms. A total of 670 copies of questionnaire were administered by hand to the respondents. However, 462 questionnaires, representing around 69% of the distributed questionnaires were retrieved and 446 questionnaires (about 97% of retrieved) were correctly filled and analysed for the purpose of this study. The questionnaire used have six sections. However, only data collected from three sections were used for analysis and discussion in this article. The data used covered the respondents’ bio-data and the data from Section D of the questionnaire covering extent of adoption of LPs in building design and construction processes. In this section, respondents were asked to select out of the 32 LPs identified in a previous that have been adopted by their firms [8]. Furthermore, data collected using Section F of the questionnaire covering perceived influence of LCPs adoption were also included in the analysis. The Statistical Package for the Social Sciences (SPSS) software package was used in analysing the data. The main type of analysis conducted is descriptive statistics. This is because of the nature of the research question. The results are presented in using Tables and Charts as shown in the next section of this paper.

4. Results and Discussion

This section presents and discusses the result of the survey conducted in the light of existing knowledge on the subject as identified in the review of literature.

4.1. Respondents Bio-Data

Respondents’ bio-data are presented in Table 1. Table 1 revealed that most of the respondents are males of ages between 16 years and 35 years, working in architectural firms with minimum of bachelor’s degree. In addition, a majority of the respondents in this study have working experience in the industry between 1 year and 5 years indicating that, they have sufficient experience to provide reliable data for this research. The result further revealed that most of the respondents are employees of architectural firms located in Lagos and Abuja. It can therefore be inferred from this result that most of the stakeholders in the Nigerian building industry are well-educated, experienced, and are young male adults.

Table 1: Respondents' Profile

Attributes	Frequency 446 (100%)
Male	324 (72.6)
Female	122 (27.4)
16-25 years	125 (28.0)
26-35 years	192 (43.0)
36-45 years	77 (17.3)
46-55 years	35 (7.8)
56 years+	17 (3.8)
Abuja	147 (33.0)
Lagos	185 (41.5)
Port-Harcourt	38 (8.5)
Kaduna	47 (10.5)
Enugu	29 (6.5)
Architectural	310 (69.5)
Building Consulting and Contracting	21 (4.7)
Quantity Surveying	115 (25.8)
Architect	256 (57.4)
Builder	34 (7.6)
Engineer	37 (8.3)
Project Manager	24 (5.4)
Quantity Surveyor	95 (21.3)
Diploma	97 (21.7)
Bachelor	252 (56.5)
Master	85 (19.1)
Doctoral	12 (2.7)
1-5	200 (44.8)
6-10	149 (33.4)
11-15	71 (15.9)
16-20	7 (1.6)
21-25	15 (3.4)
25 and above	4 (0.9)

4.2. Extent of LCPs adoption in the Nigerian building industry

In order to address one of the objectives of the study, it was important to determine the extent of LCPS adoption in the Nigerian building industry. Therefore, respondents were asked to select among the 32 LCPs identified by [8] that their firms have used in building design and construction procurement activities. The essence of this was to reveal the most adopted LCPs and extent of their adoption in the procurement of building projects in the study area. The result is as presented in Table 2.

The result presented in Table 2 reveals the number of firms that indicated that they have adopted each of these LCPs identified. This result is used to gauge the extent to which each of the LCPs have been adopted in building design and construction activities in the Nigerian building industry. From the result in Table 2 it is evident that the extent of individual practices adoption is still very low in the Nigerian building industry. In fact, the data in Table 2 shows that of the entire environment sustainable LCPs investigated the most adopted are the VDC tools with 9.19% of the respondents indicating its adoption), plan for condition and work environment with 6.38% of the respondents and TPM having only 4.1% of the respondents indicating that they have adopted this). Next to these are JIT, pull scheduling, 6 sigma, modularization and prefabrication and Kazen. This result is a clear indication that VDC is the most adopted lean tool in the Nigerian building industry, which aligns with findings from a

previous study [15] where Computer Aided Design (CAD) also known as a VDC tool was identified as a lean tool that supports the implementation of lean construction in the Saudi Arabian construction industry. This is could be because the CAD, 3D/4D (BIM) are software packages and tools that are use by most built environment professionals and easily enable them to execution the different tasks linked to them in the building industry. Other reasons could be because its adoption aligns with the traditional construction process in Nigeria as previous authors [16,17 and 18] have mentioned in their respective studies.

Table 2: Extent of Lean Practices Adoption among Sampled Firms

S/N	Lean practices	Frequency	Percentage	Ranking
1.	Visual Design Construction (VDC)*	65	9.19	1 st
2.	Total quality management	53	7.50	2 nd
3.	Team/partnering	50	7.07	3 rd
4.	Plan of conditions and work environment*	45	6.36	4 th
5.	Last planner	43	6.08	5 th
6.	Visualization tools (signpost and board for instruction on site)	31	4.38	6 th
7.	Total preventive management (TPM)*	29	4.10	7 th
8.	Health and safety improvement	28	3.96	8 th
9.	Detailed briefing	28	3.96	8 th
10.	Just-in-time (JIT)*	27	3.81	9 th
11.	Work structuring and scheduling	25	3.54	10 th
12.	Design Workshop/ big room	24	3.39	11 th
13.	Pull scheduling*	24	3.39	11 th
14.	Standardization	24	3.39	11 th
15.	Design structure matrix	18	2.55	12 th
16.	Benchmarking	18	2.55	12 th
17.	Integrated project delivery	18	2.55	12 th
18.	Target value design	17	2.40	13 th
19.	Daily clustering	16	2.26	14 th
20.	Error proofing	16	2.26	14 th
21.	Value-based management/ VSM*	16	2.26	14 th
22.	Conference management	13	1.83	15 th
23.	6 Sigma*	12	1.70	16 th
24.	Kanban System	12	1.70	16 th
25.	Prefabrication and modularization*	12	1.70	16 th
26.	On-site management	10	1.41	17 th
27.	Concurrent management	10	1.41	17 th
28.	Kaizen*	8	1.13	18 th
29.	Fail safe for quality	6	0.85	19 th
30.	Location-based management	4	0.57	20 th
31.	First run study	3	0.42	21 st
32.	Gemba walk	2	0.28	22 nd

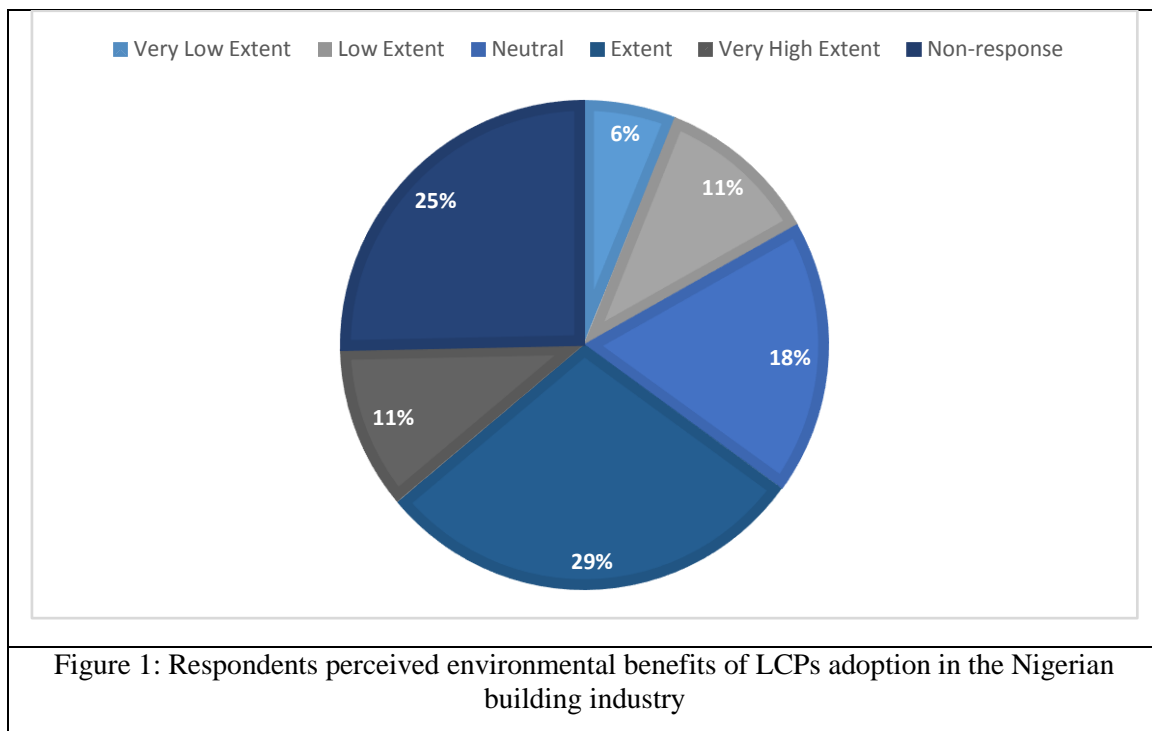
* The environmental sustainable LCPs investigated in the survey

In addition to this, based on the rankings as presented in Table 2, one can see that the environmental sustainable LCPs investigated in this study are within the first and the eighteen in the serial no (S/N).

This is an indication that environmental sustainability is achievable in the Nigerian building industry if emphasis is placed on these LCPs by stakeholders involved in the procurement of building projects.

4.3. Perceived Environmental Benefits of LCPS

In order to understand how firms viewed the benefits of adoption of LCPs in promoting environmental sustainability, the participants were asked to indicate their opinion as regards the ability of LCPs adoption to reduce the generation of material waste during building design and construction activities. Figure 1 reveals that about 29% of the respondents were of the opinion that LCPs adoption helps in reducing the generation of building material waste to an extent, 11% opined to a very high extent, about 18% were neutral, about 11% to a low extent, while 6% were of the opinion that it is helpful to a very low extent. The mean score value for the responses was 3.37 at a standard deviation value of 0.994, which implies that the respondents generally perceived that the adoption of LCPs as a veritable means for achieving environmental sustainability through reduction of material waste generation.



The result presented in Figure 1 reveals that stakeholders in the Nigerian building industry also agree with findings by [7] which indicated that the elimination of waste materials in the construction process is a very effective approach to achieving a sustainable built environment. In fact, the result of the study as presented in Figure 1 reveals that a majority of stakeholders in the Nigerian building industry agree that the adoption of LCPs on past projects handled by their firms had helped them cut down on material waste at every stage of the projects.

5.0. Conclusion

This study investigated the role of lean construction practices in environmental sustainability in the Nigerian environment. The result from this study has evidently established that adoption of LCPs has

commenced in the Nigerian building industry although to a minimal extent. The study has revealed that the categories of LCPs that support environment sustainability are among the most adopted practices in the Nigerian building industry. Based in this it can be conclude that environmental sustainability can be achieved if there is a critical mass adoption of lean practices in the Nigerian building industry. Furthermore, the stakeholders' response to benefits derivable from LCPs adoption in their firms further established that fact that their adoption can help to achieve significant reduction of material waste in the building industry and thus promoting environmental sustainability. However, it is recommended that in the adoption of LCPs by firms in the Nigerian building industry, sustainability should be considered as a goal in which the benefits of present and future users are adequately taken into consideration. This implies that only lean construction practices with proven evidence of positive impact on environmentally sustainability should be given adequate consideration id the goal is to achieve sustainability in the Nigerian built environment.

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