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Diffusion of Lean Construction Knowledge among Building Firms in the Nigerian Building Industry

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Abstract
Lean construction is an innovative construction approach as the concept originated from the Toyota production process. Thus, this study investigated the means through which knowledge about lean construction has diffused, the speed at which the knowledge diffused and factors that influenced the diffusion of lean construction knowledge among firms in the Nigerian building industry. The study was a questionnaire survey administered in five major cities of Nigeria, which were Abuja, Enugu, Kaduna, Lagos and Port Harcourt. A sample size of 446 firms were used comprising of architectural, building contracting and consulting and quantity surveying firms located in these five cities. Descriptive, factor and regression analysis was conducted on the data of the study. Findings from the study revealed that the Internet, Seminars/lectures and words from colleagues were the major means through which knowledge about lean construction diffused among stakeholders in the Nigerian building industry. While, the diffusion speed of lean construction knowledge was observed to be slow in the Nigerian building industry. In addition, qualification of stakeholders, location of firms, prior conditions of firms, characteristics of the decision-making units and communication channels were identified as factors that significantly influenced the diffusion of lean construction knowledge among firms in the Nigerian Building Industry. Therefore, for knowledge of lean construction to increase among firms in the Nigeria building industry it is important that awareness about it be increased using the identified communication channels.

Keywords: Communication channels, Diffusion, Lean construction, Nigerian Building industry, innovation

Introduction
The Nigerian building industry is a subsidiary of the construction industry; the building industry focuses on the entire building procurement process and activities. These activities include the design, planning, construction management and control with monitoring of buildings (Aziz and Hafiz, 2013). However, the construction industry has been as faced with several problems, which includes the generation and management of physical and non-physical waste (Olanrewaju and Abdul-Aziz, 2015 and Oyewobi, Ibironke, Ganiyu and Ola-awo, 2011), limited research work and collaboration, unwillingness of stakeholders towards adoption of new methods, approaches and technology. In addition are insufficiency of fund, inadequacy of local materials, and recurrent change in governments and policies (Iheme, Ngwu, Okoro, Oyoyo and Iroegbu, 2011).

Therefore, in order to tackle the problems identified as a limitation to the growth of the construction industry several researches have been conducted towards new approach and methods that can aid the reduction of waste in the building procurement process. Some of such research works resulted in

approaches such as design and build, waste efficient procurement and such that focused only on management of already generated physical waste leaving out the non-physical waste (Ajayi, *et al*., 2017).

Literature has identified lean construction as an approach that helps in the elimination of both physical and non-physical waste and still places emphasis on generating best value for the clients. Literature has further revealed that lean construction has been adopted and investigated across different countries in the world even though the extent and means through which its knowledge has diffused have been observed to be mostly left out in the investigation process (Salem, Solomon, Gnaidy and Minkarah, 2006; Aziz and Hafiz, 2013 and Sarhan, Xia, Fawzia,and Karim, 2017). Despite the fact that the lean practices adoption has been properly investigated it has been observed that its adoption is limited by different factors key among them are the skills and knowledge related barriers (Oladiran, 2008; Devaki and Jayanthi, 2014; Omran and Abdulrahim, 2015 and Sarhan *et al.*, 2017).

Since, Rogers' diffusion of innovation theory revealed that the diffusion and adoption of any innovation begins with the knowledge stage and this process can be influenced by factors such as the communication channel, prior conditions, characteristics of decision-making unit and others (Rogers, 2003). It is therefore, important that the state of knowledge and process of knowledge diffusion of lean practices be first established in other to determine the extent of its adoption.
Furthermore, some literature in the area of lean construction adoption has revealed that diffusion process of lean knowledge in the construction industry have been underrepresented. As findings from Ayarkwa *et al*. (2012) only focused on familiarity of stakeholders with lean concepts and means through which stakeholders in the Ghanaian construction industry became aware about lean construction while Odeis (2013) conducted similar research that indicated majority of stakeholders in the Kenyan construction industry heard about lean construction through either journals or the Internet. Although findings from Babalola, Ibem and Ezema (2018) indicated that there is a good familiarity of building stakeholders in the Nigerian industry with lean construction concepts, the adoption of lean practices was observed to be low, indicating there might have been other factors that influenced lean practices adoption aside stakeholder's familiarity and awareness of lean construction and practices. Thus, establishing the need to for this study. Therefore, this study's focus is to investigate the entire lean practices knowledge diffusion process and the factors that could affect Lean Practices (LPs) knowledge diffusion process. To achieve this, the study will be answering the following research questions:

Through what means did firms in the Nigerian building industry become knowledgeable about lean construction and its practices?
How fast or slow was the knowledge about lean practices perceived to have diffused among firms in the Nigerian building industry?
What factors significantly influenced the rate of lean construction knowledge diffusion among firms in the Nigerian building industry?

Literature Review

Lean Construction and Practices

Lean construction emerged from the lean production in the manufacturing sector. According to Howell (1999), the lean production emphasizes on waste reduction, flow based production management system, continuous improvements and value generation over the entire course of a production process. Meanwhile, there is always the concern whether the lean philosophy is applicable to construction due to differences between manufacturing and construction processes. The main difference is that constructed products are rooted in place, and are designed for a specific location, often both technically and aesthetically (Koskela, Huovila and

Leinonen, 2002; Salem *et al*., 2006). Nonetheless, lean production is a philosophy that comprises principles and methodologies that can be adapted to other sectors (Ansah, Sorooshian and Mustafa, 2016; Howell, 1999).

Moreover, lean production promotes objectives such as value addition and meeting customer requirements in a timely manner, which are also same with the objectives in construction (Koskela *et al*., 2002). Lean construction is characterized by clear set objectives. These objectives include maximizing project level performance for clients, concurrent design of product and process, and the application of control throughout the lifecycle of the project from design to delivery (Howell, 1999). According to Madanayake (2015), the main idea underlying lean construction is about reducing waste in processes while focusing on things that add value to the customer. It is also about improving the delivery systems of construction projects to satisfy client's need (Ansah *et al*., 2016).

In practice, lean construction is employed as a project delivery system, which involves different processes in order to move a facility from concept to clients (Koskela *et al*., 2002). In contrast to the traditional delivery system, the lean project delivery is non-linear rather it involves multiple phases that are interrelated thereby allowing construction professionals to work together across phases (Koskela *et al*., 2002). Therefore, the design of lean project delivery involves organization of a cross-functional teams, set-based design strategy, design work for value generation and flow, lessening negative iteration and design production control (Ballard, Tommelein, Koskela and Howell, 2007). In the implementation of lean project delivery in construction, many techniques and tools are used. Babalola, Ibem & Ezema (2019) identified thirty-two lean practices that have been adopted in the construction industry. Some of which includes the last planner system, just-in-time, pull scheduling, concurrent engineering, and visual design construction tools among others. Koskela *et al*. (2002) mentioned that in the implementation of some of these practices, some could be leaner than others. That is, some of the practices could help achieve the objectives of lean construction better than the others. For instance, Salem *et al*. (2006) found that increased visualization, daily huddle meetings and first run studies exceeded performance expectations, while 5s process and fail safe for quality did not exceed performance expectation on a construction site operated by a medium size construction firm in the US. Furthermore, in practice, integrated product and process models are needed for simultaneous product and process design in lean project delivery in construction (Ballard *et al*., 2007).

Factors that Influence the Diffusion and Adoption of Lean Practices (LPs)

Several researchers have investigated the factors that determine the diffusion and adoption of lean practices in different countries. While some of these factors were identified as barriers that limit their adoption, others were considered as critical success factors that encourage their adoption in the construction industry. For instance, Li *et al.* (2017) identified proper knowledge of LPs, structure and culture of the organization and market as factors that supports the implementation of lean practices in China.

Barriers to adoption of lean practices in Nigeria are categorised into attitude, management, government, skill and knowledge, resources, logistics and others to include inflation-related barriers (Oladiran, 2008). This categorisation was also adopted by Marhani, Jaapar, Bari and Zawawi (2013) and added the lean construction process related barriers as such barrier peculiar to the Malaysian construction industry. Other studies such Ahiakwo *et al*., 2012; Devaki & Jayanthi, 2014; Omran & Abdulrahim, 2015; Ayalew *et al*., 2016 identified other factors that could limit the diffusion and adoption process of lean construction across different countries. These studies however highlighted the most significant among the barriers to be those that involve the culture

and the attitude of adopters and industry, knowledge and awareness related as well as organizational and management support.

Furthermore, critical success factors were also identified that could aid the diffusion and adoption of lean construction (Coster, Engdahl & Svensson, 2014). These critical success factors are accountable for the successful application of an approach, concept or strategy (Coster *et al*., 2014). sLean construction critical success factors were categorized into resources factors, leadership factors, management and cultural factors, and skill and knowledge factors (Ogunbiyi, 2014). In addition to the factors identified by Ogunbiyi (2014) market was added as a significant factor towards the adoption of LPs in China (Li *et al*,.2017). Other studies which investigated critical success factors of LPs were Cano, Delgado, Botero and Buriano (2015); Limon (2015) and Sarhan, Olanipekun and Xia (2016).

Guiding Theory and Framework

This study is guided by Rogers diffusion of innovation theory and the Technology, Organization and Environment (TOE) Framework. The TOE framework aligns with the Rogers DOI theory and reveals the decision to adopt an innovation as being influenced by the industry and the market conditions (External Task Environment). This was identified as a gap that Rogers's DOI theory was unable to fill (Oliveira & Martins, 2011). Thus, this study incorporates the TOE framework to expand the environmental factor only.

Everett Rogers developed the Diffusion of Innovation Model in 1962, and since then the theory has been widely revised and adopted for studies in diffusion and adoption of technology and innovation. The Diffusion of Innovation (DOI) Theory helps to explain innovation diffusion and adoption both at individual and organizational levels. It further highlights how information about an innovation reaches its users (Rogers, 1983 and Sahin, 2006). Diffusion was defined as the process through which communication of innovation is carried out through some channels in a society. Innovation itself is an idea (process, service or product) perceived by a decision making unit as new. The fact that the idea is perceived to be new implies there might be some level of uncertainty in the decision making unit (a person, an organization or community). Therefore, Rogers' definitions reveal that although diffusion and adoption are stages in the DOI Theory, both cannot be seperated from each other, as diffusion is part of the processes that lead to adoption (Rogers, 1983; Sahin, 2006; Ibem *et al.*, 2016).

Rogers identified five major elements as important in the diffusion and adoption of any innovation. These elements can be instrumental to the reduction of uncertainty in the heart of the decision making unit during the process of innovation diffusion, and can, therefore, either inhibit or encourage adoption decision (Rogers, 1983 and Sahin, 2006).

On the other hand, Tornatzky and Fleischer developed the Technology, Organization, and Environment framework in 1990. The development of this model described the adoption of innovation as being affected by three key factors of technology, organization, and environment (Tornatzky and Fleischer, 1990). The TOE framework has been considerably used either independently as theoretical background for several researches on adoption of innovation or alongside theories like the Rogers DOI theory (Baker, 2012). For instance, Padilla-Vega, Sénquiz-Díaz and Ojeda (2017), while investigating factors that impact acceptance of mobile technology in the international business growth, independently used it. Also, Pan and Jang (2008) study on determinants of enterprise resource planning adoption in Taiwan communication industry was based on the TOE framework. In addition, Oliveira *et al*. (2011) and Ibem *et al*. (2016) employed both the TOE alongside DOI in their studies on innovations adoption at the organizational level thereby establishing the fact that the two theories can be used alongside each other for the study of innovation diffusion and adoption.

Diffusion of Innovation Process

Rogers (1983) established that the diffusion of innovation is a process characterised by five stages, which are knowledge, persuasion, decision, implementation and confirmation stages. This section of the study discusses briefly each of the stages. This study primary investigated the diffusion of LPs knowledge by firms in the Nigerian building industry. Thereby situating the study into one of the stage of the diffusion of innovation process that is knowledge stage. Thus the knowledge stage is discussed further.

Stage of Knowledge

This stage is when the potential adopter becomes aware of the existence of the innovation. The person finds out about the innovation by acquiring knowledge and information about the innovation. There are three types of knowledge involved at this stage, which is described as the innovation-decision process. These knowledge types are the awareness knowledge (I have heard about the innovation), the application knowledge (how to use the innovation) and the principle knowledge (how the innovation works). All this three knowledge can determine the rate of adoption of any innovation (Rogers, 1983; Rogers, 2003 and Sahin, 2006).

The awareness knowledge involves the individual taking cognisance of the existence of the innovation. This knowledge alone has the ability to make a person decide to adopt an innovation or getting more knowledge on the procedure for using the innovation. The application knowledge basically gives a better understanding of how the innovation can be used in meeting a specific need. At this point of knowledge, there is a higher chance for adoption. However, the principle knowledge might not be necessary before a person adopts the innovation as it only makes the person have a solid foundation of how the innovation operates and why it operates the way it does (Rogers, 1983; 2003). The importance of this knowledge is that it prevents misuse of the innovation which might lead to discontinuance as explained by Sahin (2006).

Factors that affect the diffusion and Adoption of Innovation

According to Rogers (2003), innovation diffusion and adoption process is influenced by several factors. The factors can either serve as inhibitors or drivers of innovation decision. This section discusses these factors, which are the perceived characteristics of the innovation, characteristics of the decision making unit, channels of communication, nature of the societal system, and efforts of the change agent (the change agent that is the promoters of the innovation and it is mostly important when the innovation has to do with product and services and not method of operation) (Rogers, 1983 and Sahin, 2006). In addition, Roger (1983) highlighted in the DOI theory that prior condition is a factor that directly has influence on the knowledge stage of the innovation diffusion process. Prior condition includes items such as previous practice, felt problems, innovativeness and societal norms. Whereas the TOE framework defines three factors that causes technological innovation adoption in an organization as the technology background of the organization, the organization structure, the external environment. Both factors stated in the DOI theory and the TOE framework can be aligned.

While aligning the TOE framework with the Rogers' DOI Theory, the technology, organization, and the environmental factors were identified as factors that influences the decision of an adopter (firms in the Nigerian building industry) to adopt an innovation such as LPs. In addition, the TOE factors also encompass the factors that influence the diffusion and adoption of innovation in the DOI theory. The Technology factors of TOE framework, includes the perceived characteristics of innovation of the DOI theory, while the Organization factors includes the characteristics of decision making unit of the DOI theory and the Environmental factors covers prior conditions and communication channels of the DOI theory.

Thus, the basic tenets of the TOE framework are that technological, organisational and environmental factors have direct influence on the diffusion and adoption of LPs as an innovation in this context. Hence, relating this to the DOI theory, it can be inferred that the knowledge of the adopter about LPs also influences adopters' decision to adopt LPs and the extent to which they will adopt LPs under study. As a result, these factors are assumed to influence both the knowledge as indicated in the DOI theory, as postulated by Rogers (2003).

Characteristics of the Innovation: are factors perceived by the intending users of the innovation. These characteristics simply mean to the users the nature of the innovation they include relative advantage, compatibility, complexity, trialability and observability as the five important characteristics of an innovation that can affect the intending adopter to be persuaded to take a decision to adopt the innovation (Rogers, 1983). These five characteristics of an innovation are known to account for between 49% and 87% of innovation adoption results around the world. They are the key factors that have to be considered in any innovation diffusion and adoption research work (Rogers, 2003 and Ibem *et al*., 2016).

Characteristics of the Decision-making Unit: The decision to adopt an innovation can be organizational or individual based decision. The decision-making unit characteristics are the socio-economic characteristics of the organization, the organizational variables, and the organizational communication behaviour (Rogers, 2003).

Communication Channels: Communication is defined as a process that involves creating and sharing of information between two or more participants with the mind of reaching a mutual understanding (Sahin, 2006). Communication is usually carried out through channels or media. The information is passed from the source to receiver through a channel (Sahin, 2006). Therefore, communication channels are means or medium through which information is passed from a source to a receiver. Diffusion is identified as a social process and precise kind of communication because it has elements that include the innovation itself, two units of adoption and channels through which it is passed. Innovation are communication either through mass media (TV, Radio, Newspapers, online channels and all such), interpersonal channels (peer to peer communications and networks, unions and organizations) or the combination of both channels (Sahin, 2006).

The communication actors in a communication channel can be homophilic or heterophilic in nature. The homophilic communication participants are characterised by similarity in attributes such as beliefs, education, and socioeconomic status and such, while the heterophilic participants have dissimilarity in attributes (Sahin, 2006). Some authors (e.g., Rogers, 1983; Rogers, 2003; and Sahin, 2006) emphasised that innovation diffuses better where there is some element of homophily in the communication channels.

Nature of Social System: this encompasses the environmental factor of the TOE framework. As Roger (2003) defines a social system is as a group of people or set of units that are jointly involved in meeting a need (Rogers, 2003). This set of people has same focus and are united by same value system and purpose. The nature of the social system where the innovation is being diffused can influence the adoption of the innovation. The society is actually the place or environment where any innovation is communicated. It could stand as an organization or even an industry; it covers the norms of the society, which include the nature and culture of the industry (Rogers, 1983; Rogers, 2003 and Sahin, 2006).

Efforts of Change Agents: Communication agents are also referred to as change agent in the TOE framework. The presence or absence of change agents that introduce and encourage organization towards the adoption of innovation is more influential

when the innovation is related to services and products. The environmental factors of the TOE framework cover the industry (structure, policy and nature), the presence of providers of innovation (change agents), the government, and regulatory bodies the organization belongs too. For instance, extreme competition in the market can inspire organization towards the adoption of innovations. Furthermore, influence of large and established firm in the industry can push other firms towards adoption of innovation. Therefore, they can thrive in the competitive market as well as influence firms outside the sector of the organization (Baker, 2012).

Other environmental factors that can influence innovation adoption in firms are life cycle of the industry to which the firm belongs. This is because growth in the industry also has direct influence on the organizations in the industry and, supports infrastructures and amenities that can encourage the ease of adoption. Such support features include presence of skilled labour and right expertise, favourable government policies, and availability of social amenities (Baker, 2012).

Research Methods

This research was an exploratory research, achieved by using quantitative approach for data acquisition. Firms in the Nigeria building industry were the unit for analysis. Copies of structured questionnaire were administered for the collection of the data. The questionnaire was administered to firms of architecture, building contracting and consulting and quantity surveying firms in five selected cities in Nigeria namely Abuja (North central zone), Kaduna (Northwest zone), Enugu (Southeast zone), Port-Harcourt (South south zone), and Lagos (Southwest zone). These cities were purposively selected because they had the highest number of registered firms located within them among other cities in their respective geopolitical zones, based on the data provided by the Architect Council of Registered Architects (ARCON), Council of Registered Builders of Nigeria (CORBON) and the Nigerian Institute of Quantity Surveyors (NIQS). However, the Northeast zone was exempted because of insecurity problems.

The sample size for this study was calculated to be 446 firms (40% of the total population). For even selection from each firms' category, 40% of each category of firms in each city was calculated as shown in Table 1. This sample size method is appropriate because it has been widely among social scientist. According to Nwana (1981); Alreck and Settle (1985) and Adekeye and Apeh (2019) 40.0% or more can be carefully chosen if the population is a few hundreds, while if many hundreds, 20.0% of the population is appropriate. In addition, if the population is a few thousands 10.0% of the population can be selected and if several thousands, 5.0% or less will do for the sample. Therefore, it is assumed that the population frame for this study is just a few hundred as the total population of firms is 1116 as shown in Table 1. Therefore, the sample size used for the purpose of the study was 446 firms as presented in Table 1.

The sample size for this study was calculated from the sample frame drawn from the data provided by Architects Registration Council of Nigeria (ARCON, 2016), the Council of Registered Builders of Nigeria (CORBON, 2017), and the Nigerian Institute of Quantity Surveying (NIQS, 2017 https://niqs.org.ng/). The total sample frame for the study was 1116 (see Table 1).

Furthermore, a multistage sampling approach was used to select the firms for the study. Firstly, clustering sampling was used as areas with natural clusters of firms in the building industry were identified within each city; secondly, a random sampling was conducted to select the firms to be used within the identified clusters. However, a person was selected from each firm to represent the firm in filling the questionnaire.

The questionnaire used for the study was designed such that the first section was used to gather general information about the respondents while the second section

covered information on the diffusion of lean knowledge and practices among firms in the Nigerian building industry. Firstly, respondents were asked to indicate channels, through which their firms became aware about lean construction and its practices. Secondly, respondents were asked to indicate the influence of selected communication channels on the diffusion of lean practices knowledge within their firm and among firms in the Nigerian building industry using a 5-point Likert type scale ranging from "1" for *Very Low Influence* to "5" for *Very High Influence.* While respondents were asked to indicate the speed of lean knowledge diffusion within respondents' firm and among firms in the Nigerian building industry based on a similar scale ranging from "1" for *Very Slow* to "5" for *Very fast*. Lastly, respondents were asked to indicate factors that influenced the extent of diffusion of lean practices knowledge among firms in the Nigerian building industry using a same scale as aforementioned. In addition, 670 copies of the questionnaire were administered in the aforementioned five cities in Nigerian between June and July 2018, 462 copies (69% of administered) of the questionnaire were retrieved and 446 copies (97% of retrieved) were properly filled and used for the purpose of analysis. The type of analysis conducted on the data were descriptive, factor and regression analysis using Statistical Package for Social Sciences (SPSS) software package. The results of the survey are presented and discussed in the next section.

Results and Discussion

Respondents Profile

Results from Table 2 shows that most of the respondents were male, only 27.4% were females. This reveals that the industry might be a male dominant industry. This result supports that of Akomolafe and Mohammed (2015) revealing that although the rate at which women have been employed into the Nigerian construction industry has increase in recent years, they still constitute just about 22% of the total employees. Another important findings from Table 2 is that most of the respondents were young adults with the age range of 16 to 35 years (71%).

Table 1: Distribution of Study Sample Size

Cities/Type of Firms	Architecture	Building Contracting and Consulting	Quantity Surveying	Sample Population	Sample size
Lagos (Population)	330	12	120	462	-
Sample size	132	5	48	-	185
Abuja (Population)	253	31	84	368	-
Sample size	101	12	34	-	147
Port-Harcourt(Population)	67	6	22	95	-
Sample size	27	2	9	-	38
Kaduna (Population)	70	5	43	118	-
Sample size	28	2	17	-	47
Enugu (Population)	56	-	17	73	-
	22	-	7	-	29
Total	-	-	-	1116	446

Table 2: Respondents Profile

Sex	**Percentage (%) (N=100%)**
Male	72.6
Female	27.4
Age Grouping (Years)	**Percentage (%) (N=100%)**
16-25	28.0
26-35	43.0
36-45	17.3
46-55	7.8
56 and above	3.8
Cities	**Percentage (%) (N=100%)**
Abuja	33.0
Lagos	41.5
Port-Harcourt	8.5
Kaduna	10.5
Enugu	6.5
Type of Firms	**Percentage (%) (N=100%)**
Architectural	69.5
Building Consulting and Contracting	4.7
Quantity Surveying	25.8
Position	**Percentage (N=100%)**
Architect	57.4
Builder	7.6
Engineer	8.3
Project Manager	5.4
Quantity Surveyor	21.3
Highest Qualification (Degree)	**Percentage (N=100%)**
Diploma	21.7
Bachelor	56.5
Master	19.1
Doctoral	2.7
Working Experience Groups (Years)	**Percentage (N=100%)**
1-5	44.8
6-10	33.4
11-15	15.9
16-20	1.6
21-25	3.4
25 and above	0.9

Communication Channels of Lean Construction Knowledge in the Nigerian Building Industry

Result of means through which the knowledge of lean construction and its practices have diffused among firms in the Nigerian building industry is presented in Table 3. Respondents were asked to select among the twelve communication channels identified from literature which one have helped in the diffusion of lean construction knowledge. Table 3 shows that among the communication channels investigated in this study the Internet (35.7%), Seminars/Lectures (24.4%) and Colleague (18.4%) ranked from the 1st to the 3rd respectively. This implies that majority of the Nigerian building industry stakeholders became aware about lean construction and its practices through the three aforementioned means of communication.

The result as presented in Table 3 aligns with findings by Ayarkwa *et al.* (2012) revealing that majority of Ghanaian construction industry stakeholders became mostly aware and knowledgeable about lean construction through interaction among colleagues. In addition, the result as presented in Table 3 further aligns with Odeis (2013) which indicated that professionals in the Kenyan construction

industry became aware about lean construction and its practices either through journals or through the Internet. This is an indication that for proper diffusion of lean construction knowledge in the industry regardless of the country the Internet and information from colleagues are key communication channels, which should not be neglected. This was also asserted by Sahin (2006) that communication is one among the factors that influences the diffusion of knowledge about any innovation as well as determines the rate of adoption or rejection of the innovation.

Diffusion Speed of Lean Construction Knowledge

Diffusion of any innovation can be measured by the increase of knowledge about the innovation and the speed at which the knowledge moved in a system. Therefore, in order to determine the speed at which knowledge about LPs has been communicated in the Nigerian building industry, respondents were asked questions on how they perceive the speed of LPs knowledge within their firm and among other firms in the Nigerian building industry. The result is presented in Table 5.

Table 4 reveals that majority of the respondents were not unsure about the speed of LPs knowledge diffusion in the Nigeria building industry. The findings indicate that 31.2% opines that the speed of lean construction knowledge's diffusion within their firm was slow as only 20.6% are of the opinion that it is fast. While, the majority 42.4% suggested that the speed of LPs knowledge was slow among other firms in the Nigerian building industry as only 10,7% indicated it was slow. This result reveals that although, Babalola, Ibem and Ezema (2018) stated that the level of awareness about lean practices among Nigerian building industry professional was high, and their familiarity with lean construction concepts and definitions was good the speed of their knowledge seems to be slow. The speed of diffusion of innovations differs depending on the factors that strongly influence the diffusion of the innovation (Rogers, 2003). This implies that the speed of LPs observed to be slow as revealed in Table 4 is dependent on the factors that influenced the diffusion of the knowledge, which will be discussed in the next paragraphs.

Table 3: Communication channels of lean construction based on respondents' opinion

s/n	Mean of Diffusion	Percentage	Rank
	Internet	35.7	1st
	Seminars/Lectures	24.4	2nd
	Colleague	18.4	3rd
	School	16.6	4th
	Workshops	16.4	5th
	Professional Associates	13.2	6th
	Conferences	11.9	7th
	Social media	11.0	8th
	Mass Media	5.4	9th
	Congress	4.5	10th
	Business Associates	3.4	11th
	Materials Supplier	3.1	12th

Table 4: Speed of LPs Knowledge Diffusion

Speed of LPs diffusion	Scale	Frequency	Percentage
Speed of diffusion Within Firm	Very Slow	50	11.2
Mean Score=2.52	Slow	89	20.0
SD=1.02	Unsure	215	48.2
	Fast	75	16.8
	Very Fast	17	3.8
Among other firms in the Nigerian building industry	Very Slow	53	11.9
	Slow	136	30.5
Mean Score=2.36	Unsure	209	46.9
SD=0.92	Fast	38	8.5
	Very Fast	10	2.2

Influence of Identified Factors on Lean Construction (LC) Knowledge's Diffusion

This section discusses respondents' response to factors that influences LC knowledge diffusion in their firms. The study investigated 17 factors drawn out of literature aside communication channel which was earlier independently investigated. However, in order to group the 17 investigated factors properly under the categories of factors from DOI theory and TOE framework capable of influencing the diffusion process of innovation. A factor analysis was conducted on the 17 items using Principal Component Analysis (PCA). Table 5 presents the result of the PCA showing the factors loaded into each category and the percentage at which each category of factors influences the diffusion of LPs knowledge in the Nigerian building industry.

Furthermore, the percentage variance accounted for the three components extracted was about 56.41% suggesting that these components do have a high influence on the diffusion of LPs knowledge in the Nigerian building industry as Table 6 further validates this opinion. Table 5 further revealed that factor 1 (Characteristics of the decision making units and experience of previous adopters of LPs) had seven items loaded on it, while factor 2 (perceived characteristics of LPs) and Factor 3 (prior conditions of firms) has five items loaded on them respectively. In addition, the result of the PCA reveals a correlation coefficient between all the items as not less than 0.3 except item 5 (ease to imitate it) with 0.22. The Karser-Oklin Measure of Sampling Adequacy (KMO) value was 0.89 and the Bartlett's Test of Sphericity was significant at a value of 0.00. This result indicated that the factors and the items loaded in each component are well correlated and of great significance.

In addition, Tables 6, present a descriptive analysis of respondents' perception about factors that influences diffusion of LPs knowledge among firms in the Nigerian building industry. These factors are grouped as prior conditions related factors, characteristics of decision-making unit and experience of previous adopters of LPs related factors and characteristics of LPs related factors (see Table 5).

Table 6 reveals Factor - Prior condition consists of variables such as presence of innovative employees**,** management usual support for increase of knowledge through seminars and workshops, adoption of innovation as an organizational norm, firms' perceived benefits from its adoption, and previously felt problem while using the traditional procurement practices. Table 6, further reveals that all the variables that indicated prior conditions of firms in this study have high influence on the diffusion of LPs in the industry based on the perception of the respondents, as all have mean scores value of more than 3.0. However, "firm's perceived benefits of LPs adoption" had the highest influence with mean value score of 3.31 and standard deviation of 1.19.

Table 5: Factor Analysis of factors that Influence LPs Diffusion

Factors	% Variance accounted for	Variables	Component Loadings
Factor 1	22.20	Market demand for its use	0.784
Characteristics of the Decision making Units and Experience of Previous adopters of LPs		How management sees its compatibility with project at hand	0.762
		Positive reports from other firms who have used it on projects	0.689
		Strong persuasive influence of communication channels	0.633
		How fast it was adopted by other firms	0.622
		Specific request of Clients for LPs to be used on their projects	0.574
		Firms innovativeness	0.445
Factor 2	17.38	Ease of use	0.695
Perceived Characteristics of LPs		Ease to imitate it	0.671
		How observable it processes are	0.624
		Its competitive advantage over other practices	0.586
		How easy it is to be tried	0.500
Factor 3	16.84	Presence of innovative Employees	0.792
Prior Conditions of Firms before LPs diffusion		Management usually support increase of knowledge through seminars, workshops and such	0.697
		Adoption of innovational is an organizational norm	0.658
		Firms perceived benefits from its adoption	0.443
		Previously felt problem while using the traditional procurement practices	0.373

Furthermore, Table 6 shows perceived influence of characteristics of decision-making unit on LPs knowledge diffusion in the Nigerian building industry. It revealed that among the variables in this category, only "How fast it was adopted by other firms in the industry" had low influence on the diffusion of LPs knowledge as it had a mean score value of 2.92 and standard deviation of 0.95. The other variables all had mean score values greater than 3.0, which signifies that all other variables that measures the characteristics of the decision making unit had high influence on the diffusion of LPs knowledge in the Nigerian building industry. The variables perceived by respondents to have influence includes drive for its adoption due to market demand for LPs use, management view of its compatibility with project at hand, positive reports of use from other firms, strong persuasive influence of communication channels, speed of its adoption by other firms, and specific request by clients for its use and firms' innovativeness.

In addition, Table 6 shows the result on respondents rating of influence of the characteristics of LPs on LPs knowledge spread (diffusion). The result revealed that all the variables in this category highly influence the diffusion of LPs knowledge based on the perception of the respondents. However, "its ease of use" (mean score value= 3.32 and SD =1.06) was ranked as the variable in this category with the highest influence on LPs diffusion.

The result presented in Table 6 aligns with the factors mentioned as enablers of innovation in the construction industry from findings of Gambatese and Hollowell (2011). That research revealed that upper management support, support of owner/client, culture of the organization, presence of innovative employee and

communication among firms about the innovation were among the identified enablers of any innovation (Gambatese and Hollowell, 2011). Furthermore, the result presented in Table 6 aligns with findings from Gao, Li and Tan (2013) indicating compatibility of any innovation with the project or processes in existence and performance justification which entails perceived benefits from its use due to reports of adopter were part of the key factors that influences the diffusion of innovation in the construction industry. In addition, the result presented in Table 6 aligns with assertion by Roger (2003) that the characteristics of an innovation, which include relative advantage, compatibility, trialability, complexity, and observability significantly predicts the diffusion of an innovation with a variance between 49% and 87%.

All aforementioned findings from literature have help established the that fact that most of the factors investigated in the categories of "Prior condition, characteristics of decision making units and characteristics of the LPs" are enablers to the diffusion of LPs knowledge in the Nigerian building industry as presented in Table 6 except "how fast LPs was adopted by other firms in the industry". Thus, if stakeholders pay attention to it could aid the adoption of LPs in the Nigerian building industry on the long run.

Factors that significantly that influences the diffusion of LPs knowledge

To establish if the investigated factors in this study have significant influence on lean practices diffusion in the Nigerian building industry, a regression analysis was conducted. In this case, "diffusion of LPs" was the dependent variable and the independent variables were characteristics of the decision-making Units, perceived characteristics of LPs, prior conditions of firms, communication channels, and the respondents' demographic characteristics. Diffusion of LPs, was measured by combining the result of the extents of LPs awareness among firms in the Nigerian building industry which result have been published in Babalola, Ibem and Ezema (2018) revealing extent of knowledge that LPs can be used in building design and construction (49%), LC aids effectiveness and productivity on building projects (44%), LC is different from traditional building procurement approach (36.3%), LPs aids timely project delivery (47.3%) and LPs aids cost effective project delivery (47.8%).

The regression model is statistically significant (sig = 0.000, at $p < 0.001$). This implies that the independent variables significantly influence diffusion of LPs knowledge in the Nigerian building industry. Furthermore, the value of R square for the regression model was 0.541. This shows that the factors (characteristics of the decision-making units, perceived characteristics of LPs, prior conditions of firms, communication channels, and the respondents' demographic characteristics) investigated in the study influences diffusion of LPs knowledge in the Nigerian building industry with about 54.1%. From the model by Rogers (2003) on diffusion of innovation, it was mentioned that the key factors that affect the diffusion and adoption of any innovations are the communication channels, efforts of change agents, nature of the societal system, perceived characteristics of the innovation, and characteristics of the decision making unit. However, the result of this research shows that these factors are very important, but there are other factors that account for about 36% of LPs knowledge diffusion that were not investigated in this study. Table 7 presents the coefficients of the regression analysis.

The result presented in Table 7 revealed qualification, location, prior conditions of the firm, characteristics of decision-making unit, perceived characteristics of LPs and communication channels as factors that significantly predicts the diffusion of LPs in the Nigeria building industry. It is evident from Table 7 that the characteristics of the decision-making unit seem to be the most significant factor since it had β value of 0.347, next to which was the communication channels (β=0.292), and the

perceived characteristics of innovation with β value of 0.139 was the least among the factors that significantly influenced LPs adoption.

This result aligns with the diffusion of innovation theory, which indicated that the innovation, communication channels, communication time and social system were key elements towards the diffusion of any innovation (Gambatese & Hollowell, 2011; Ibem & Laryea, 2015). In addition, the result also covers the technology, organization and environmental factors as indicated by the Technology Organization and Environment (TOE) framework for adoption of innovation (Baker, 2012) which both forms the theories on which this study was hinged. As the perceived characteristics of LPs covers for the innovation and technology, characteristics of the decision-making unit and qualification covers for the social system and organization and communication channels and location covers for the environment as expressed in the TOE framework.

Table 6: Descriptive analysis of response on factors that influences LC knowledge diffusion

Factors that influences Lean construction knowledge diffusion	Mean Score	SD	Rank
Prior Conditions			
Firms perceived benefits of LPs adoption	3.31	1.19	1st
Previously felt problems while using the traditional building practices	3.25	1.11	2nd
Adoption of innovation is an organizational norm	3.19	1.21	3rd
Management usually support increase of knowledge through seminars, workshops and such	3.08	1.24	4th
Presence of innovative employees	3.05	1.11	5th
Characteristics of Decision-making Unit and Experience of Previous adopters of LPs			
Positive reports from other firms that have adopted it	3.40	1.05	1st
Firms' innovativeness	3.36	1.07	2nd
Drive for its adoption through market demand for its use	3.19	1.01	3rd
Specific request by clients for its use	3.17	1.15	4th
Management view of its compatibility with the project at hand	3.15	1.20	5th
Strong persuasive influence of the communication channels	3.07	1.09	6th
How fast it was adopted by other firms in the industry	2.92	0.95	7th
Perceived Characteristics of LPs			
Its ease of use	3.32	1.06	1st
How observable its processes are?	3.22	1.08	2nd
How trainable it is	3.22	1.02	2nd
Its competitive advantage	3.20	1.06	3rd
Ease to imitate it	3.05	1.02	4th

Note: Any mean score value *less than 3.0 indicate low influence, 3.0 indicate neutral, while values greater than 3.0 indicates high influence*

Other factors which significantly influence the diffusion of LPs knowledge in the Nigeria building industry includes qualification perhaps as majority of the respondents (56.1%) had a minimum of Bachelor degree (see Table 1). This could be because level of education can increase the relative advantage of a firm towards the diffusion and adoption of any innovation as mentioned by Rogers in Sahin (2006). This findings aligns with the opinion by Abu-Shanab (2011) that education can significantly predict peoples intention towards adoption of an innovation as the research revealed a significant difference in the respondents with high school education, bachelor degree, and higher graduate degree as regards their intention to adopt the use of Internet banking which was identified as an innovation.

In addition, the location of firms was also identified as a significant factor that influenced the diffusion of LPs knowledge in the Nigerian building industry, this could be because the cities selected for the purpose of this study were those with the largest population of firms showing their possible

nearness to source of knowledge about the innovation. For instance, cities like Lagos, Abuja and Port-Harcourt are large commercial cities and it is expected that there should be high demand for the use of innovations and technology in the delivery of building projects. This findings aligns with Lengyel et al. (2020) which mentioned that geographical characteristics like distance from the source of the innovation and the size of the town can predict the diffusion and high adoption of any innovation.

Furthermore, Table 7 presents the tolerance and VIF value for each of the independent variables of LPs knowledge diffusion. The tolerance and VIF values reveal if there is any multicollinearity among the variables, however, the variables studied here showed no multicollinearity as all tolerance value were below 0.1 and not all VIF values are above 10. This implies the independent variables are not closely related, meaning that each variable has its own peculiar characteristics.

Table 7: Coefficients of the Regression Analysis

Factors	Std error	Standardized Coefficients Beta	t < 2	Sig. < 0.05	Tolerance > 0.1	VIF < 10
Gender	.086	-.039	-1.028	.305	.939	1.065
Age	.048	.079	1.588	.113	.551	1.813
Organization	.037	.073	1.576	.116	.636	1.573
Position	.028	-.077	-1.656	.099	.628	1.592
Qualification	**.043**	**.143**	**3.293**	**.001**	**.729**	**1.372**
Working experience	.043	-.084	-1.645	.101	.527	1.897
Location	**.028**	**.200**	**5.108**	**.000**	**.891**	**1.122**
Prior condition	**.061**	**.279**	**4.843**	**.000**	**.412**	**2.428**
Characteristic of decision making unit	**.064**	**.347**	**6.247**	**.000**	**.444**	**2.252**
Perceived characteristics of LPs	**.070**	**-.139**	**-2.373**	**.018**	**.398**	**2.510**
Communication channels	**.049**	**.292**	**7.287**	**.000**	**.854**	**1.171**

*** Significant at p < 0.05**

Conclusion and Recommendation

Based on the result of this study it has been revealed that for proper diffusion of lean construction knowledge among stakeholders in the Nigerian building industry and in the construction industry at large emphasis should be placed on making information about lean practices adoption and its process readily available on the Internet. This is because based on the result of this study the Internet sufficed as the most important communication channel of LPs in the Nigerian building industry. Furthermore, the study has been able to exposed that for diffusion of lean construction and practices to be speedy the managements of the organization must be supportive of the innovation as the study revealed that the speed observed in the diffusion of lean construction knowledge within the firms could be due to such supports. In addition, the study has been able to establish qualification, location of the firms, prior conditions of the firms, characteristics of decision-making unit, perceived characteristics of LPs and communication channels as significant predictors of lean construction and practices knowledge diffusion in the Nigeria building industry. It is therefore recommended for knowledge about lean construction and any innovation to speedily diffuse in the Nigerian building industry, management and stakeholders should give in full support and as well channel resources into sharing information about benefits and expertise of the innovation among each other.

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