ASSESSING THE APPLICATION OF LEAN TECHNIQUES FOR BUILDING MATERIALS WASTE MINIMISATION IN ABUJA, NIGERIA

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Abstract

Lean construction techniques have been known globally as a production system with a high capacity of waste minimisation. However, previous studies reveal the dearth of effective strategies for application of the lean techniques in material waste minimisation for building projects in Nigeria. This research assessed the strategies for application of lean techniques in material waste minimisation of building projects in Abuja, Nigeria. The study adopted a survey design approach using quantitative data. Data were purposively collected through well-structured questionnaire administered to 240respondents, including, project managers, contractors, heads of waste management departmentsof 80-active building construction sites that are practicing lean within Abuja. A total of 189 questionnaires were retrieved from the240administered. The collected data were analysed using descriptive methods, including Mean Item Score (MIS) and Relative Importance Index (RII). The study revealed that the important lean techniques for material waste minimisation in building projects were: visual management; plan for waste disposal management; plan for space utilisation management, optimise value/value identification, good supply chain management, and visual management, with average RII values of 0.78. The lean techniques advanced in this study were all considered important in material waste minimisation. The study concluded that creation of lean awareness programs; efficient training and education of construction personnel on lean techniques; just in time operations; and provision of management supports for lean implementation in waste minimisation, are the key strategies for applying lean techniques in material waste minimisation. It was recommended that effective application of the lean techniques and these strategies would translate into a drastic reduction in the quantity of material waste generation in building projects.

Keywords: Building projects, Lean techniques, Material waste, and Waste minimisation

INTRODUCTION

Construction waste is a global problem which can have great effect on time, and quality of projects (Nagapan and Rahman, 2012). The problem of construction waste all over the world remains unresolved, as has been shown by various authors reporting on the situation (Osmani, 2011; Babatunde, 2012; Ameh and Itodo, 2013;Saidu and Shakantu, 2018).For instance, 10-15% of materials delivered to construction sites end up as wastein the United Kingdom (UK); the United States (US) generate164m tonnes of construction waste annually; and China alone generates 30% of the world's municipal solid waste, with its Construction and Demolition (C&D) waste representing 40% of the country's municipal solid waste (Saidu and Shakantu, 2018).

This problem of material waste is not any different in Nigeria, for instance, Umar (2019) found that the amount of materials used on site significantly predicts the quantity of material wastegenerated onconstruction sites in Nigeria. Thus, for

every 100 houses built in Nigeria, there are sufficient waste materials to build another 10 houses (Ameh and Itodo, 2013). This reiteratesthat 10% of materials delivered to building construction sites end up as waste (Osmani, 2011; Saidu and Shakantu, 2018). Though, Babatunde (2012) emphasises that the problem of construction material waste is well known in Nigeria, still it seems not to be given the recognised attention it deserves and thus, building construction sector is often classified at the bottom of the ranking of reports regarding the efficiency of the production management techniques (Bajjou and Chafi, 2018).

Considering this global problem of material waste and the need to improve construction performance, theEgan publication of the UK in 1998 led the government to establish initiatives and management philosophies, such as the partnering, benchmarking, lean construction, among others to improve performance and curtail waste (Ayinde, 2018). The lean construction concept has *been viewed to have more impact in* waste management than other alternatives which focus on individual process and productivity improvements (Ogunbiyi, Oladapo and Jack, 2013). Lean production philosophy which was developed by the Toyota production system has been successful in achieving maximum profits and value for money to customers (More, Charhate and Sinha, 2016). Adoption of the lean technique in the construction industry became necessary because of the needs to meeting project objectives (cost, quality and timely completion); the need to reduce uncertainty and waste in the production process, by adding value to construction activities; and the need of meeting clients' requirements (Arditi, 2016; Kokate & Darade, 2018).

Studies have revealed that the lean approach has made a tremendous achievement in construction project performance of developed nations (USA, the UK, Demark, Australia, and so forth) and some developing nations (Brazil, China, among others) (Ballard and Howell, 2003). Lean construction philosophy considers construction materials waste as potential threat that hinders flow of value to the client which must be eliminated (Maru, 2015).. Arditi (2016) therefore, concludes that material waste generation on construction sites can be eliminated/minimised by applying lean construction techniques in material waste management process of building projects.

Despite the number of literature on waste management techniques across the world, and several efforts by construction practitionersto manage the occurrence of material waste in building projects, such as education and training on waste management, waste recovery systems, *adequate site storage and so forth* (Kokate and Darade, 2018; Umar, 2019), wastage of materials still remains a serious problem requiring urgent attention in the Nigerian construction industry (Saidu and Shakantu, 2018; Umar, 2019). This problem could be linked to slowness of the industry in adapting modern techniques,like the lean thinking for waste minimisation in construction projects (Saidu and Shakantu, 2018). Also, there is little understanding of the benefits of lean techniques in waste minimisation (Adam& Abdulhamid, 2017; Kokate& Darade, 2018).

Previous studies reveal the dearth of effective strategies for application of the

lean techniques in material waste minimisation for building projects (Bajjou and Chafi, 2018; Adam and Abdulhamid, 2017). This study therefore, assesses strategies for application of lean techniques in material waste minimisation of building projects in Abuja, Nigeria. To achieve the highlighted aim, the following research questions were answered: What are the various lean techniques that are relevant at stages of materials waste minimisation?What are the challenges faced in the application of the lean techniques for material waste minimisation for building construction projects? And what are the strategies for effective application of the lean techniques in materials waste minimisation?

Classification of Waste in Building Construction Projects

Waste is a product or material that is unwanted and has no residual value (Nagapan and Rahman, 2012). Construction waste can be clustered into two groups, namely, the physical and non-physical waste,while thephysical waste comprises a mixture of inert and non-inert materials arising from construction, excavation, renovation. demolition, roadwork and other construction-related activities. The non-physical wastes are the immaterial waste, in-direct waste or non-physical waste. Such as mistakes that require rectification, process steps that are not needed, unnecessary movement of employees, and people waiting for the conclusion of upstream activities. Another example includes time overruns and cost overruns (Umar, 2019).

Lean Techniques Relevantto Building Construction Projects

Some of the lean techniques that are relevant to building construction projects are presented as:

Last Planner System (LPS): aims to change the focus of control from the workers to the flow of work better to direct works through continuous learning and to cause the work to flow across production units in the best achievable sequence of rate (Aziz and Hafez, 2013).

Value stream mapping (VSM):The tool is used to visually represent the product flows. VSM is a lean thinking analogue tool for depicting production processes and for improving conditions and understanding for reducing variability and waste(Sarhan and Fox, 2013).

5S Work organisation:The main idea behind the 5Ss (Sort, Sort/Straighten, Shine, Standardise, Sustain) is to acquire, maintain and improve the standard set-up inorderto efficiently decrease waste, all done in an organised manner (O'Connor and Swain 2013).

Visual Management (VM):This is based on the fact that most people respond to visual prompts and get more involved in things that they can see clearly and understand. The VM can be used to immediately communicate unambiguous happenings (O'Connor and Swain, 2013).

Just in Time (JIT):At each step the main aim of JIT is to deliver timely, accurate quantities of the correct material. The three elements of JIT are people, plant and systems (Almeida, 2002).

Standardised work:In standardising, the production rate for each process must be the same as Takt time (average time between start of production of one unit and the next unit) with no variability. Aparticular task be performed in the same manner throughout to decrease set-up time and process time variation, so that the product design is standardised (Moghadam, 2014).

Partnering:Partnering is a long-term commitment which includes two or more organisations with the aim to achieve a particular business objective together by obtaining the maximum potential of the resources available at each point (Sarhan,Xia, Fawz and Karim, 2017).

Daily huddle meeting:This planning is implemented during the execution phase of the project by holding daily meetings to coordinate work activities (Kumar and Rumasamy, 2013).

Challenges Facing Lean Application in Materials Waste Minimisation

A significant challenge identified in the application of lean techniques for materials waste minimisation is the unwillingness of the management in the contracting firms to train their workers on lean construction techniques, especially foreign workers in the country (Omran and Abdulrahim, 2015). Other challengeismanagement related issues, such as lack of management commitment and high expectations;technical related issues, such as the complexities of lean construction implementation, educational issues which include inadequate knowledge of lean construction concepts amongst construction industry operators; and financial issues, such as the high cost of implementinglean construction (Bashir *et al.,* 2015). In China, Shang and Pheng (2014) found government related issues such as stringent requirements and approvals to be a major challenge. Similarly, Olamilokun (2015) revealed that corruption and/or corruptivetendencies from government agencies is a barrier to the implementation of lean constructionin Nigeria.

Strategies for Addressing the Challenges of Applying Lean Techniques in Material Waste

In an attempt to identify ways of addressing these challenges, Omran and Abdulrahim, (2015) identified creation of Lean awareness programs, staff training and education on Lean techniques, and government policies. However, as part of cultural changes, Bashir, Suresh, Oloke, Proverbs andGameson (2013) suggested thatconstruction organisations should use very simplified terms to convey ideas about leanconstruction in the organisation policy. Similarly, as part of a commitment to lean constructionpractices, management should acquire necessary managerial skills to oversee thesuccessful implementation of lean construction during project delivery (Shang and Pheng,2014). For instance, employing a participatory style of management which allows employeeparticipation in decisions leading to lean construction is likely to build their trust and supportfor the implementation of lean construction (Bashir *et al.,* 2015;Shang and Pheng, 2014).

Stages of Material Waste Minimisation

The stages involved in material waste minimisation resolve around construction project lifecycle from pre-construction stage of material waste minimisation which starts from project inception (proposal) to the final stage of contract award. The activities in the pre-construction stage include, planning phase (feasibility, outline proposal etc); design phase (scheme and detailed design); and estimating phase (quantity take off). The construction stage therefore,include activities such as materials procurement, site management and construction management phase

These activities if not properly managed and controlled, would contribute to the generation of material waste (Dennis, 2010).

RESEARCH METHODOLOGY

The study adopted a survey design approach using quantitative data. Survey design was deemed suitable for this study because the lean techniques considered are those identified from the literature to which their applicability in construction project is to be verified in this study. Data were collected through structured questionnaire administered to respondents within Abuja, because it is one of the metropolitan cities in Nigeria with many ongoing building construction activities and many organisations that are practicing lean. The population consisted of 80-active construction sites obtained from the Federation of Construction Industry (FoCI directory, 2018) that are practicing lean within Abuja. The population of 80-active construction sites were broken into sample frame constituting one each of the following respondents: Project managers; contractors; and heads of waste management departments/units, making a total of 240 respondents within the study area. These respondents were selected because they are the key players in the application of the lean techniques on construction sites. Therefore, a total of 189 questionnaires were retrieved from the 240 questionnaires administered. 183 were found valid for the analysis, and the remaining five (5) were deemed invalid, because of poor responses. The 183 represents an effective response rate of 76% and this was considered suitable for analysis (Alreck and Settle, 1985).

This study adopted purposive/judgmental sampling technique in order to select only the construction project sites that have acquire experience in applying lean techniques in material waste minimisation on construction site. Thus, not all construction sites were visited. Blaikie (2010) noted that judgmental sampling is used for selecting cases of a particular type in a population. A multi-choice type questionnaire was designed for this research. The questionnaire contains tables and check-boxes for easy selection of options by respondents. The questionnaires were structured in a manner that allows respondents to select from the answer choices provided. The questionnaire reflects the major areas of the study interest, thereby, providing information relevant to the study objectives and answering the research questions. The questionnaire asked questions on a 5-point Likert scale.

The questionnaire was divided into two (2) main parts. Part A - was related to demographic information of the respondents and their companies. Part B- asked questions about lean techniques relevant to stages of materials waste minimisation in building project; the challenges faced in applying the lean techniques; and strategies for effective application of the lean techniques.

Descriptive method of analysing data was employed in this study. Relative Importance Index (RII) was used to examine the important lean techniques and the key challenges for applying lean techniques in material waste minimisation. Mean Item Score was used analysed on the average the strategies for applying the lean techniques in material waste minimisation. The data processing was done with the aid of Statistical Package for the Social Sciences (SPSS 23) software version.

RESULTS AND DISCUSSION

Lean techniques relevant to the pre-construction stage of materials waste minimisation

Table 1 indicates that the major lean techniques relevant to planning phase of material waste minimisation by the respondents are: Total Quality Management; visual management; optimising value/value identification; waste disposal management; reducing process cycle time; and supply chain management, because they had RII values of 0.81, 0.81, and 0.80s respectively. This confirms the result of Small and Yasin (2011) and Marhani, Azmi and Bari (2012) that the most important lean techniques at the planning stage of construction process is the Total Quality Management and visual management.At design phase, the relevant lean techniques commonly applied in building construction projects by the respondents are: optimising work content; optimising product system; and defined work process, with RII values of 0.83, 0.82 and 0.80 respectively.

Moreover, at the estimating stage of materials waste minimisation, the relevant lean techniques by the respondents are: value stream mapping and root cause analysis (Pareto, 5 whys) each with RII values of 0.80. However, training and development, error proofing and supplier involvement, were deemed to be the least techniques relevant in the estimating stage of building construction projects because they had RII of 0.60, 0.62 and 0.63 respectively.

On the overall, the lean techniques relevant to the pre-construction stage of building projects are: visual management; waste disposal management; space utilisation management were all ranked first with average RII values of 0.78. They were considered by the respondents as the important lean techniques at the preconstruction stage of building project. These results are in line with the findings of O'Connor and Swain (2013) and Sarhan and Fox (2013) on the important lean techniques for minimising non-value added activities in construction.

A close look at the result in the Table 1 shows that all the 37 lean techniques had an average RII value of 0.72, implying that to a considerable extent all the lean techniqueswere considered 'important'and capable of positively influencing the materials waste minimisation process.

Table 1: Lean Techniques Relevant to the Pre-Construction Stage of Building Project

	Lean Principle/Techniques	Planning phase		Design phase		Estimating phase		Overall average		
A	**Customer Focus**	**RII**	**Rnk**	**RII**	**Rnk**	**RII**	**Rnk**	**RII**	**Rnk**	**Decision**
1	Customer Relationship	0.77	8	0.71	14	0.64	27	0.71	20	Important
2	Customer Involvement	0.73	29	0.68	21	0.71	15	0.71	20	Important
3	Flexible resources	0.71	37	0.62	29	0.78	4	0.71	20	Important
4	Optimise value/value identification	0.80	3	0.63	26	0.77	6	0.73	13	Important
B	**Continuous Improvement**									
5	Metrics (Productivity, Quality, Safety)	0.76	9	0.53	34	0.75	11	0.68	32	Moderate
6	Organisational learning	0.75	19	0.55	33	0.63	30	0.64	38	Moderate
7	First run studies	0.75	19	0.60	31	0.68	20	0.68	32	Moderate
8	Huddle meting	0.75	19	0.78	7	0.76	6	0.76	7	Important
C	**Supply of material**									
9	Supply Chain Management (SCM)	0.80	3	0.74	11	0.76	6	0.77	4	Important
10	Just in Time	0.75	19	0.69	20	0.69	17	0.71	20	Important
11	Supply involvement	0.73	29	0.72	14	0.62	33	0.69	28	Moderate
12	Supplier development	0.72	34	0.72	14	0.76	6	0.73	13	Important
D	**Waste Elimination**									
13	Reduce process cycle time	0.80	3	0.71	16	0.70	16	0.74	11	Important
14	Waste awareness and consciousness	0.76	9	0.73	12	0.75	11	0.75	9	Important
15	Value stream mapping	0.76	9	0.73	12	0.80	1	0.77	4	Important
16	Space utilisation	0.76	9	0.78	7	0.79	3	0.78	1	Important
17	Optimize Product system	0.74	25	0.82	2	0.76	6	0.77	4	Important
18	Waste disposal management	0.80	3	0.79	4	0.76	6	0.78	1	Important
E	**People Involvement**									
19	Workforce/Workers involvement	0.76	9	0.78	7	0.68	20	0.74	11	Important
20	Top management involvement	0.73	29	0.79	4	0.68	20	0.73	13	Important
21	Training development	0.73	29	0.71	16	0.68	35	0.71	20	Important
22	Team Work	0.79	6	0.70	19	0.64	27	0.71	20	Important
23	Organizational commitment	0.74	25	0.59	32	0.65	26	0.66	36	Important
F	**Planning & Scheduling**									
24	Last Planner System	0.76	9	0.63	26	0.68	20	0.69	28	Moderate
25	Percent Plan complete indicator	0.75	19	0.67	25	0.68	20	0.70	26	Important
26	Collaborative planning	0.74	25	0.70	19	0.67	25	0.70	26	Important
G	**Quality of material**									
27	Total Quality Management (TQM)	0.81	1	0.71	16	0.66	25	0.73	13	Important
28	Error proofing Poka-yoke	0.76	9	0.68	21	0.62	33	0.69	28	Moderate
29	Response to defect	0.72	34	0.68	21	0.68	19	0.69	28	Moderate
30	Root cause analysis (Pareto, 5 why's)	0.71	37	0.63	26	0.80	1	0.71	20	Important
31	Fail Safe for quality	0.79	6	0.67	25	0.78	4	0.75	9	Important
H	**Standardisation of Processes**									
32	Optimise work content	0.76	9	0.83	1	0.69	17	0.76	7	Important
33	Defined work process	0.76	9	0.80	3	0.64	27	0.73	13	Important
34	Takt time	0.74	25	0.68	21	0.74	13	0.72	18	Important
I	**Transparency in Management**									
35	Visual Management	0.81	1	0.78	7	0.74	13	0.78	1	Important
36	Work place organization	0.58	38	0.71	16	0.63	30	0.64	38	Moderate
37	Building information Modelling (BIM)	0.73	29	0.79	4	0.63	30	0.72	18	Important
	General Average							**0.72**		**Important**

Lean techniques relevant to stages of material waste minimisation in building projects

Table 2 indicates that the major lean techniques at material procurement phase are: ensuring Total Quality Management; supply chain management; optimising value/value identification, visual management, with RII values of 0.81, 0.80, and 0.80s respectively. Table 3 also reveals that, the most important lean techniques relevant to the construction stage of material waste minimisation are: Building Information Modelling; Total

Quality Management; waste disposal management and supply chain management with RII values of 0.83, 0.81 and 0.80s respectively.

The most ranked techniques for the site management phase of building construction projects are: Takt time; quick response to defect; waste awareness, and optimising value/value identification with RII of 0.89, 0.87 and 0.85 respectively.

The most important lean techniques relevant to the construction stage of building materials waste minimisation are: optimise value/value identification, supply chain management, visual management and building information modelling with the most RII.These results are in line with the findings of O'Connor and Swain (2013); Sarhan and Fox (2013); Small and Yasin (2011); Marhani *et al.* (2012) on the important lean techniques for minimising non-value added activities in construction.

However, a close look at the result in the Table 2 shows that all the identified 38 lean techniques relevant to construction stage had an average RII value of 0.76. This implies that to a considerable extent all the lean techniqueswere considered 'important'and capable of positively influencing the materials waste minimisation at the construction stage of building projects.

Challenges in the Application of Lean Techniques for Material Waste Minimisation

Table 3 reveals that lack of appropriate training on lean techniques application with RII value of 0.95 was ranked 1st; this is followed by poor communication amongst the people involved with RII value of 0.87. Other major challenges by the respondents include lack of top management support and commitment (0.86); and poor project definition (0.85). These findings corroborate Omran and Abdulrahim (2015); Bashir *et al.*, (2015) who highlighted unwillingness of management to train their workers on lean construction techniques and lack of awareness as major challenges in applying lean techniques.

Strategies for Application of Lean Techniques in Material Waste Minimisation

Table 4shows that efficient training and education of construction personnel on lean techniques with MIS value of 4.42; creation of lean awareness programs with MIS value of 4.29; just in time operations (4.15); and managerial skills and support for lean implementation in waste minimisation (4.10); and good communication and coordination on site (4.08), were the key strategies for material waste minimisation through lean techniques. These results are in line with the findings of Suresh *et al.* (2012); Bashir *et al.* (2015); Shang and Pheng (2014) on the strategies for applying lean techniques in waste minimisation in building projects.

Table 2: Lean Techniques Relevant to the Construction Stage of Building Project

	Lean Principle/Techniques	Material Procurement		Construction Management		Site Management		Overall average		
A	**Customer Focus**	**RII**	**Rnk**	**RII**	**Rnk**	**RII**	**Rkn**	**RII**	**Rnk**	**Decision**
1	Customer Relationship	0.78	7	0.77	10	0.78	17	0.78	10	Important
2	Customer Involvement	0.72	33	0.72	32	0.66	33	0.70	33	Important
3	Flexible Resources	0.71	37	0.70	36	0.74	27	0.72	32	Important
4	Optimise/ identification of value	0.80	2	0.79	6	0.85	3	0.81	1	Important
B	**Continuous Improvement**									
5	Metrics (Productivity and Quality)	0.75	17	0.76	12	0.78	17	0.76	17	Important
6	Organizational Learning	0.74	23	0.74	23	0.75	26	0.74	25	Important
7	First Run Studies	0.74	23	0.73	28	0.68	32	0.72	32	Important
8	Huddle Meting	0.75	17	0.75	19	0.78	17	0.76	17	Important
C	**Supply of material**									
9	Supply Chain Management	0.80	2	0.80	3	0.84	6	0.81	1	Important
10	Just in Time	0.75	17	0.74	23	0.79	13	0.76	17	Important
11	Supply Involvement	0.73	29	0.73	28	0.76	24	0.74	25	Important
12	Supplier Development	0.72	33	0.71	35	0.67	33	0.70	33	Important
D	**Waste Elimination**									
13	Reduce process cycle time	0.79	5	0.79	6	0.76	24	0.78	10	Important
14	Waste consciousness awareness	0.76	11	0.76	12	0.85	3	0.79	5	Important
15	Value stream mapping	0.76	11	0.77	10	0.77	23	0.77	13	Important
16	Space Utilization	0.75	17	0.75	19	0.81	9	0.77	3	Important
17	Optimize Product system	0.74	23	0.74	23	0.69	31	0.73	31	Important
18	Waste disposal management	0.79	5	0.80	3	0.78	17	0.79	5	Important
E	**People Involvement**									
19	Workforce/Workers involvement	0.76	11	0.76	12	0.84	6	0.79	5	Important
20	Top management involvement	0.74	23	0.73	28	0.78	17	0.75	23	Important
21	Training development	0.73	29	0.73	28	0.78	17	0.74	25	Important
22	Team Work	0.78	7	0.78	8	0.70	31	0.75	23	Important
23	Organizational commitment	0.73	29	0.72	32	0.78	17	0.74	25	Important
F	**Planning & Scheduling**									
24	Last Planner System	0.76	11	0.76	12	0.85	3	0.79	5	Important
25	Percent Plan complete indicator	0.75	17	0.75	19	0.82	8	0.77	14	Important
26	Collaborative planning	0.74	23	0.75	19	0.80	10	0.76	17	Important
G	**Quality of material**									
27	Total Quality Management	0.81	1	0.81	2	0.72	29	0.78	10	Important
28	Error proofing Poka-yoke	0.76	11	0.76	12	0.79	13	0.77	13	Important
29	Response to defect	0.72	33	0.72	32	0.87	2	0.77	13	Important
30	Root cause analysis (Pareto, 5 why's)	0.72	33	0.70	36	0.80	10	0.74	25	Important
31	Fail Safe for quality	0.78	7	0.78	8	0.81	9	0.79	5	Important
H	**Standardization of Processes**									
32	Optimize work content	0.76	11	0.76	12	0.71	30	0.74	25	Important
33	Defined work process	0.75	17	0.76	12	0.79	13	0.76	17	Important
34	Takt time	0.73	29	0.74	23	0.89	1	0.79	5	Important
35	Work sequences	0.74	23	0.74	23	0.80	10	0.76	17	Important
I	**Transparency in Management**									
36	Visual Management	0.80	2	0.80	3	0.79	13	0.80	3	Important
37	Work place organization	0.63	38	0.61	37	0.67	32	0.63	35	Moderate
38	Building information Modelling	0.77	10	0.83	1	0.79	13	0.80	3	Important
	General average							**0.76**		**Important**

Table 3: Challenges in the Application of Lean Techniques for Material Waste Minimisation

SN	Challenges in the application of lean techniques for material waste minimisation	RII	Ranking
1	Lack of appropriate training on lean	0.95	1
2	Poor site communication	0.87	2
3	Lack of top management support and commitment	0.86	3
4	Poor project definition	0.85	4
5	Long implementation period	0.83	5
6	Delay in materials delivery	0.80	6
7	Materials scarcity	0.80	6
8	Lack of supply chain integration	0.79	8
9	Lack of long-term relationship with suppliers	0.79	8
10	Unsuitable organizational structure	0.78	10
11	Lack of agreed implementation methodology	0.78	10
12	Difficulty in understanding concepts	0.77	12
13	Lack of equipment	0.76	13
14	Lack of technical skills	0.76	13
15	Dependency of onsite design components rather than standardized components	0.76	13
16	Inadequate pre-planning	0.75	16
17	Lack of client and supplier involvement	0.75	16
18	poor designs	0.74	18
19	Incomplete designs	0.74	18
20	Lack of long-term commitment to change and innovation	0.72	20
21	Lack of standardisation	0.70	21
22	Lack of buildable designs	0.70	21
23	Extensive use of subcontractors	0.70	21
24	The fragmented nature of the construction industry	0.60	23

Table 4: Strategies for Effective Application of Lean Techniques in Material Waste Minimisation

S/N	Strategies for material waste minimisation through lean techniques	MIS	Ranking
1	Staff training and education on lean construction techniques	4.42	1
2	Creation of lean awareness program	4.29	2
3	Just in time operations	4.15	3
4	Managerial skills and support for lean implementation in waste minimisation	4.10	4
5	Good communication and coordination on site	4.08	5
6	Proper storage of materials on site	4.07	6
7	Change of attitude of workers towards the handling of materials	4.07	6
8	Vigilance of supervisors	4.02	8
9	Adherence to standardized dimensions	3.97	9
10	Checking materials supplied for right qualities and volumes	3.95	10
11	Employment of skilled workmen	3.88	11
12	Early and prompt scheduling of deliveries	3.85	12
13	Mixing, transporting and placing of concrete at the appropriate time	3.86	12
14	Accurate and good specifications of materials to avoid wrong ordering	3.79	13
15	Adoption of proper site management techniques	3.78	14
16	Careful handling of tools and equipment on site	3.73	15
17	Weekly programming of works	3.67	16
18	Accurate measurement of materials during batching	3.65	17
19	Encourage re-use of waste materials in projects	3.65	17
20	Access to latest information about types of materials on the market	3.64	19
21	Purchasing raw materials that are just sufficient	3.59	20
22	Minimising rate of design changes	3.55	21
23	Using materials before their expiry dates	3.48	22

CONCLUSION

Lean construction techniques have been known globally as a production system with a high capacity of waste minimisation. However, previous studies reveal the dearth of effective strategies for application of lean techniques in material waste minimisation for building projects in Nigeria. This research assessed the strategies for application of lean techniques in material waste minimisation of building projects in Abuja, Nigeria. It is concluded that the major lean techniques relevant to the pre-construction stage of material waste minimisation are: Total Quality Management; planning for visual management; optimising value/value identification; waste disposal management plan; reducing process cycle time; adoption of good supply chain management; value stream mapping and root cause analysis (Pareto). At the construction stage, the important lean techniques are: optimise value/value identification, supply chain management, visual management and building information modelling. The study concludes further that efficient training and education of construction personnel on lean techniques;creation of lean awareness programs; just in time operations; managerial skills and support for lean implementation in waste minimisation; and good communication and coordination on site are the key strategies for applying lean techniques in material waste minimisation.

RECOMMENDATIONS

Mangers of building construction projects should consider applying the relevant lean techniques as they would translate into a drastic reduction in the quantity of material waste generation. It is also recommended that the strategies for effective application of lean techniques identified in this research be given close look as they have tendencies of reducing the volume of material waste to be generated in building project.

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