

Lean Construction Practices and Construction Waste Management in Lagos State, Nigeria

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ABSTRACT

Rapid urbanization in megacities such as Lagos, Nigeria, has intensified construction waste generation, creating environmental and municipal waste management challenges. This study investigates the integration of Lean Construction Management (LCM) principles with environmental waste management strategies to support sustainable urban development. A quantitative cross-sectional survey design was adopted. A structured questionnaire was administered electronically to construction professionals in the built environment, including builders, engineers, architects, quantity surveyors, and project managers. From a study population of 6,875 registered professionals, the target sample was 371 ($e = 5.05\%$). A total of 166 valid responses were retrieved (44.74% of target), yielding an effective precision of 7.67% at 95% confidence. Data were analyzed using descriptive statistics, the Relative Importance Index (RII), and Exploratory Factor Analysis (EFA). Findings demonstrate a high baseline awareness of LCM, with 30.1% reporting very high awareness. Reliability testing yielded Cronbach's alpha values of 0.87 (Awareness), 0.98 (Waste Types), 0.98 (Benefits), and 0.98 (Strategies). EFA confirmed a unidimensional structure for each construct: Waste Types (KMO = 0.963, 73.56% of variance), Benefits (KMO = 0.918, 89.03%), and Strategies (KMO = 0.931, 85.13%). All items loaded above 0.80. RII ranking identified poor coordination between trades (RII = 0.784), poor communication (0.764), and rework/variation/negligence (0.757) as the most significant waste-generating factors. Value Stream Mapping (0.793) and Continuous Improvement (0.792) emerged as the most important strategies for enhancing LCM adoption. The findings suggest that embedding Lean principles within construction workflows may support site-level waste reduction and sustainable urban development, although the perception-based design does not establish causal impacts.

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INTRODUCTION

Global waste levels continue to climb as a result of expanding populations, rapid city growth, industrial advancement, and unmanaged economic expansion. Low-income developing regions are forecasted to bear the heaviest burden of this rise (Sharma & Jain, 2019). The role of waste management in achieving sustainable development is emphasized in several international development agendas, and visions. At the core of Lean Construction and environmental waste management is UN Sustainable Development Goal 12 (Responsible Consumption and Production). Lean principles achieve SDG 12 by systematically eliminating material waste, overproduction, and process inefficiencies, which in turn advances sustainable infrastructure (SDG 9), resilient urban design (SDG 11), and climate action (SDG 13) (United Nations, 2025).

Construction and demolition waste remains a significant environmental and resource-management challenge in both developed and developing countries. Globally, construction and demolition waste is estimated to account for at least 30% of solid waste generation, highlighting the substantial contribution of the construction sector to overall waste generation (Soto-Paz et al., 2023). In Nigeria, the challenge is particularly evident, as studies have reported inadequate and unsustainable waste-management practices within construction projects. For instance, (Aboginije et al., 2021), in a study of construction professionals in Lagos metropolis, found that existing construction and demolition waste management strategies were not sustainable enough.

Similarly, (Ogunseye et al., 2023) reported that open dumping, burning and landfilling remain common approaches to construction and demolition waste disposal in Nigeria. At the project level, (Oyebanjo et al., 2023) identified material storage and handling, operational factors, design and documentation, as well as procurement as major sources of material wastage on construction sites in Lagos, with material wastage estimated at between 18% and 25%. More broadly, (Abah et al., 2024) found that Nigerian construction professionals had only moderate awareness of environmental sustainability, with waste generation, air pollution, and resource depletion ranked as the most significant environmental impacts of building activity reinforcing the need for more sustainable construction practices nationally. These findings demonstrate that the challenge in Lagos extends beyond the disposal of construction waste to the processes and practices through which material waste is generated. However, construction waste should not be understood solely in terms of physical materials discarded from construction sites. Within the Lean Construction framework, waste also refers to activities and processes that consume resources without creating value for the client or the final product. These may include waiting, unnecessary transportation and movement, excess inventory, overproduction, defects, rework, and unnecessary processing. While some of these non-value-adding activities do not constitute physical waste themselves, they can contribute indirectly to material losses through rework, damage, inefficient handling, design changes, and other process

inefficiencies. Consequently, distinguishing physical construction waste from Lean's broader concept of process waste is important when considering the potential contribution of Lean Construction to environmental waste reduction.

Lean Construction provides a process-oriented approach to addressing these inefficiencies by identifying and reducing non-value-adding activities while improving workflow, resource utilization, and value delivery. Although Lean primarily emerged as an approach to improving construction-process efficiency, its emphasis on waste reduction and resource optimization has implications for environmental sustainability (Degani & Cardoso, 2002). Lean Construction has also been associated with practices that can support reduced material consumption, recycling, reduced energy use, and lower environmental impacts (Monem, 2024). Thus, Lean Construction provides a potential pathway for complementing conventional construction and demolition waste-management approaches with greater emphasis on waste prevention at the source.

Existing studies in Lagos have provided important evidence on construction and demolition waste-management strategies and the sources of physical material wastage. However, these studies have largely examined waste management and material wastage as separate issues, with less emphasis on how Lean Construction principles can be used to address the operational, handling, procurement, and organizational factors that contribute to construction waste generation. This creates a need to examine the relationship between Lean Construction practices and construction waste reduction within the Lagos construction context. Such an approach shifts attention from managing waste after it has been generated towards preventing waste through improved construction processes, resource utilization, and organizational practices.

Against this background, this study investigates the application of Lean Construction Management principles to construction waste reduction in Lagos State, with particular attention to the operational, material-handling, procurement, and organizational factors associated with waste generation. The study further examines the perceived benefits and strategies for strengthening Lean Construction implementation. By connecting process-level waste reduction with physical construction waste management, the study contributes to the discussion on integrating Lean Construction with environmental waste-management practices and their potential role in supporting more sustainable urban development in Lagos State.

MATERIALS AND METHODS

This study adopted a quantitative cross-sectional survey design to examine the awareness and application of Lean Construction principles and their potential contribution to

construction waste reduction and environmental waste management in Lagos State, Nigeria. A quantitative approach was considered appropriate because it enables the collection and statistical analysis of numerical data and the examination of relationships among variables (Ghanad, 2023; Creswell & Creswell, 2018).

Target Population and Sampling Frame

Data were collected using a structured questionnaire designed around a five-point Likert scale. The questionnaire targeted professionals within the built environment, including Builders, Architects, Quantity Surveyors, Project Managers, and Engineers. The instrument covered respondents' awareness and use of Lean Construction principles, as well as operational processes, procurement practices, material handling, organizational culture, and other factors contributing to construction waste generation.

The study population comprised construction professionals operating in Lagos State. The sampling frame was derived from the 2024 official registers of the following professional bodies: the Architects Registration Council of Nigeria (ARCON), the Nigerian Institute of Building (NIOB), the Council for the Regulation of Engineering in Nigeria (COREN), and the Nigerian Institute of Quantity Surveyors (NIQS). The total target population was $N = 6,875$, comprising Engineers (2,890), Architects (1,931), Quantity Surveyors (1,159), and Builders (895). Project Managers were included as a fifth stratum because they occupy decision-making roles in construction projects, even though they are not registered under a single professional body.

Sample Size Determination and Response Rate

The sample size was determined using the Taro Yamane's (1967) formula at a confidence level of 95% with an adjusted precision level of $e = 7.67\%$ (0.0767) for a population of $N = 6,875$ yields an optimal minimum required sample size of $n = 166$:

$$n = \frac{N}{(1 + N \times e^2)}$$

Where n = sample size, N = population, and e = margin of error.

Substituting $N = 6,875$ and solving for a target sample of 371 respondents gives an effective precision of approximately 5.05% $371 = \frac{6,875}{1 + 6,875 \times 0.0505^2}$

The initial target was therefore set at 371 respondents, corresponding to approximately 5% precision at 95% confidence.

Proportional stratified random sampling was employed across professional disciplines to ensure representative coverage. The target sample was allocated proportionally across strata as follows:

Table 1: Stratum Sample Targets (n = 371)

Stratum	Population (N_h)	Proportion	Target (n_h)
Engineers	2,890	42.04%	156
Architects	1,931	28.09%	104
Quantity Surveyors	1,159	16.86%	63
Builders	895	13.02%	48
Total	6,875	100%	371

Within each stratum, respondents were selected by simple random sampling using a computer-generated random number sequence (Microsoft Excel RAND function) applied to the numbered sampling frame.

Electronic questionnaires were distributed via Google Forms to randomized professional contact lists. A total of 166 valid responses were retrieved (Builders = 47, Engineers = 37, Quantity Surveyors = 33, Project Managers = 30, Architects

= 19). This yielded an effective response proportion of 44.74% relative to the 371 targets, which aligns with response rate norms in organizational and built-environment survey research (Baruch & Holtom, 2008).

Recounting the achieved sample of 166 against the same Yamane formula:

$$166 = \frac{6,875}{1 + 6,875 e^2} \rightarrow e 0.0767$$

The 166 achieved responses therefore correspond to an effective precision level of 7.67% at 95% confidence. This confirms that the achieved sample satisfies Yamane's criterion at a margin of error below 8% and meets the minimum sample size criteria for Exploratory Factor Analysis and Relative Importance Index calculations (Hair et al., 2019).

Questionnaire Design

Data were collected using a structured questionnaire designed around a five-point Likert scale. The questionnaire was divided into five sections:

- i. Section A — Demographic and professional information (profession, education, experience, organization type)

- ii. Section B — Awareness of Lean Construction Management
- iii. Section C — Types and sources of construction waste (operational, procurement, handling/logistics, and cultural/organizational factors)
- iv. Section D — Perceived benefits of Lean Construction on project delivery
- v. Section E — Strategies for enhancing Lean Construction adoption

Sections B–E used a five-point Likert scale (5 = Very High, 4 = High, 3 = Moderate, 2 = Low, 1 = Very Low). The full questionnaire is provided as Supplementary Material S1.

Instrument Reliability

Internal consistency was assessed using Cronbach's Alpha and McDonald's Omega (Table 2). The Awareness construct was initially tested with five items; one item ("awareness sufficiency among professionals") exhibited a negative item-rest correlation and was removed, improving reliability from $\alpha = 0.52$ to $\alpha = 0.87$ (4 items). All other constructs exceeded the recommended 0.70 threshold (Nunnally, 1978).

Table 2: Reliability Statistics

Construct	No. of Items	Cronbach's α	McDonald's ω
Awareness	4	0.868	0.868
Waste Types	20	0.982	0.982
Benefits	10	0.981	0.981
Strategies	10	0.975	0.976

The very high internal consistency values ($\alpha > 0.97$) for Waste Types, Benefits, and Strategies may partly reflect response uniformity across the Likert scales, a common phenomenon in professional survey samples; this should be interpreted alongside the unidimensional EFA results reported in the Results section.

The Relative Importance Index (RII) was computed as:

$$RII = \frac{\sum(W \times X)}{A \times N}$$

Where:

(W) = weight assigned to each factor by respondents to each factor (1 = Very Low, 2 = Low, 3 = Moderate, 4 = High, 5 = Very High)

(X) = frequency of each response assigning each weight

(A) = highest possible weight (i.e. 5 for very high and 1 for very low)

(N) = total number of respondents (= 166)

RII values range from 0 to 1, with higher values indicating greater relative importance. Factors were ranked in descending order of RII within each of the four descriptive thematic categories.

Exploratory Factor Analysis

Exploratory Factor Analysis (EFA) was conducted on the

three multi-item constructs (Waste Types, Benefits, and Strategies) to validate their underlying structure. Sampling adequacy was assessed using the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity. Factors were extracted using Principal Axis Factoring on the Pearson correlation matrix with Varimax rotation. The number of factors to retain was determined by three criteria: (i) Kaiser's eigenvalue-greater-than-one rule; (ii) the scree plot inflection point; and (iii) parallel analysis. Items with factor loadings below 0.50 or cross-loadings above 0.40 were considered for removal.

RESULTS AND DISCUSSION

The study achieved 166 valid responses, representing 44.74% of the initial target sample of 371. This response proportion is considered adequate for survey research involving hard-to-reach professional population. The first section of the questionnaire presented the demographic information of the respondents, including gender. From the responses received, 56.6% identified as male, while 43.4% identified as female. However, this does not necessarily impact the research's outcome, as the study's aim is not gender-specific.

Table 3: Gender Distribution of Respondents

Variables	Characteristics	Frequency	Percentage
Age Group	21 - 30 years	106	63.9%
	31 - 40 years	52	31.3%
	41 - 50 years	7	4.2%
	50 years and above	1	0.6%
	Total	166	100%
Profession	Quantity Surveyor	33	19.9%

Variables	Characteristics	Frequency	Percentage
	Builder	47	28.3%
	Engineers	37	22.3%
	Architect	19	11.4%
	Project Manager	30	18.1%
	Total	166	100%
Years of Experience	Less than 1 year	42	25.3%
	1 – 5 years	58	34.9%
	6 – 10 years	45	27.1%
	11 – 15 years	18	10.8%
	Over 15 years	3	1.8%
	Total	166	100%
Educational Qualification	Bachelor's Degree (B.Sc/B.Tech)	108	65.1%
	National Diploma (OND)	2	1.2%
	Higher National Diploma (HND)	9	5.4%
	Master's Degree (M.Sc)	36	21.7%
	PhD	11	6.6%
	Total	166	100%
Professional Affiliation	NIOB	56	33.7%
	NIQS	40	24.1%
	NIA	33	19.9%
	NSE	20	12.0%
	Total	166	100%
Type of Organization	Medium-scale construction firm	61	36.7%
	Large-scale construction firm	61	36.7%
	Small-scale construction firm	36	21.7%
	Government agency	8	4.8%
	Total	166	100%
Type of Construction Project	Residential	83	50.0%
	Institutional	36	21.7%
	Commercial	34	20.5%
	Industrial	13	7.8%
	Total	166	100%
Area of Specialization	Contractors	84	50.6%
	Clients	55	33.1%
	Consultants	24	14.5%
	Sub-Contractors	3	1.8%
	Total	166	100%

The survey in Table 3 reveals that the majority of participants (63.9%) are aged 21-30 years, reflecting a younger demographic, with a significant portion (28.3%) working as Builders. Most respondents have 1-5 years of experience (34.9%), and the highest educational qualification among them is a Bachelor's degree (65.1%). This suggests a relatively educated and early-career workforce.

In terms of professional affiliation, NIOB has the largest representation (33.7%), followed by NIQS (24.1%). Additionally, medium and large-scale construction firms dominate the employment landscape, representing 36.7% of respondents. Residential projects (50.0%) and contractors (50.6%) were the most common specializations.

Analysis of Questionnaire According to the Research Questions

Awareness of Lean Construction Management Principles and their Relevance to Environmental Waste Management and Sustainability among Construction Professionals

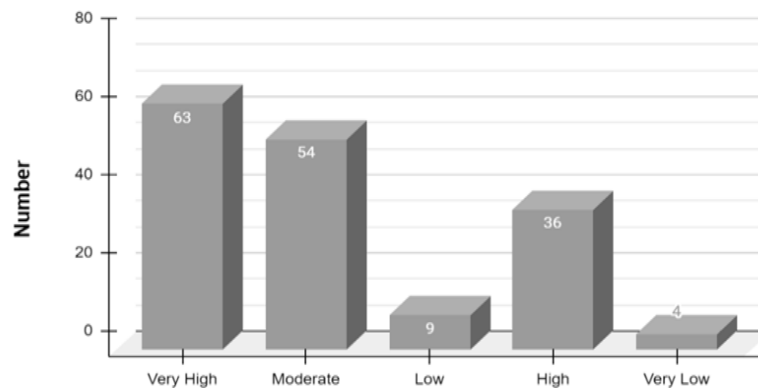


Figure 1: Level of Awareness of Lean Construction

As illustrated in Figure 1, the data shows that 30.1% of respondents have a very high awareness of lean construction, while 33.7% report moderate awareness. High awareness is noted by 16.9%, suggesting good knowledge overall.

However, 10.2% have low awareness, and 4.2% report very low awareness, indicating room for further education on lean construction principles.

Respondents' Level of Agreement Regarding Relevance of Lean Construction to Environmental Waste Management and Sustainability

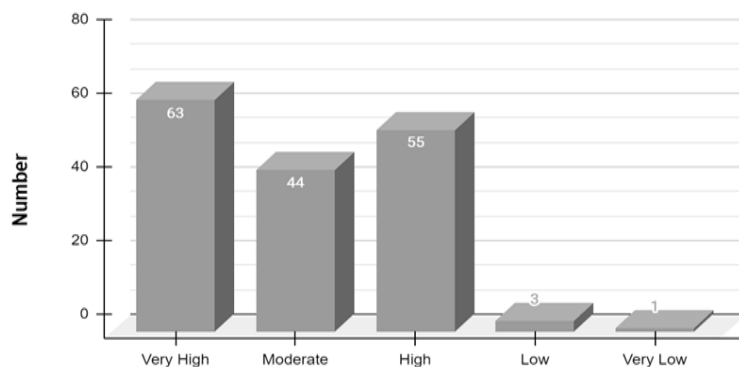


Figure 2: Level of Agreement on the Relevance of Lean Construction to Environmental Waste Management and Sustainability

The data from Figure 2 shows that 21.7% of respondents strongly agree on the relevance of lean construction, indicating broad recognition of its importance. High agreement is reported by 9.0%, while moderate agreement (15.1%) suggests some acknowledgment of lean practices but

less certainty about their effectiveness. Only 3.0% report low agreement, and 0.6% express very low agreement, indicating an overall positive perception of lean construction.

Respondents' Participation and Experience with Lean Construction Projects and Environmental Waste Reduction

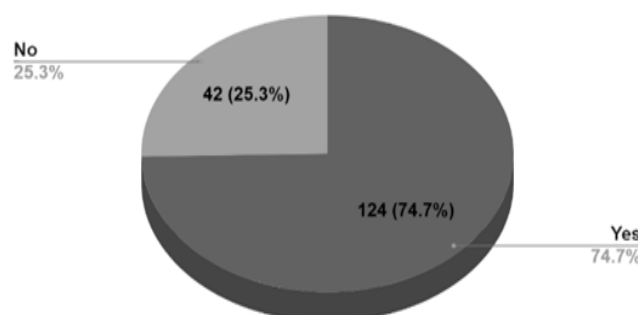


Figure 3: Respondents' Level of Participation in Lean Construction

Figure 3 reveals that 74.7% of respondents have participated in a lean construction project, indicating widespread exposure. However, 25.3% have not yet engaged with lean practices in their projects.

Frequency of Lean Construction use in Project Delivery

Table 4: Respondents' Frequency of Lean Construction Use in Project Delivery

Level of Frequency	Frequency	Percentage
Always	44	26.5%
Often	58	34.9%
Occasionally	36	21.7%
Rarely	19	11.4%
Never	9	5.4%
Total	166	100%

Table 4 shows that lean construction is widely adopted, with 26.5% "Always" and 34.9% "Often" using it. Another 21.7% use it "Occasionally." However, 11.4% "Rarely" and 5.4% "Never" use lean methods, indicating limited engagement for a small group.

Respondents' Formal Training or Education in Lean Construction Principles

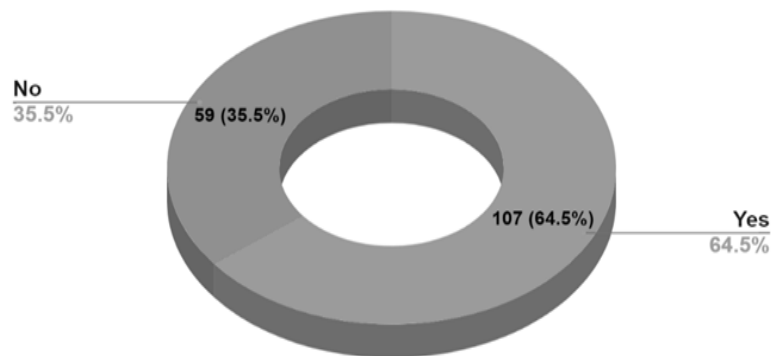


Figure 4: Formal Training in Lean Construction Principles Among Respondents

The doughnut chart (Figure 4) shows that 64.5% of respondents have received formal training in lean construction, while 35.5% have not. This suggests substantial formal exposure to lean principles, though a notable gap remains for those without formal education in this area.

Perceived Importance of Lean Construction for Environmental Sustainability

Table 5: Respondents' Perception of the Importance of Lean Construction in Environmental Sustainability

Level of Importance	Frequency	Percentage (%)
Very High	78	47.0
High	49	29.5
Moderate	29	17.5
Low	7	4.2
Very Low	3	1.8
Total	166	100

Table 5 shows that 47.0% of respondents rated Lean Construction as "Very High" in terms of its importance for waste management, while 29.5% rated it "High." Moderate importance was reported by 17.5% of respondents, whereas 4.2% rated it "Low" and 0.6% "Very Low." Overall, the

findings indicate that Lean Construction is widely perceived as important for reducing construction waste, improving resource efficiency, and supporting environmental sustainability in the construction industry.

Respondents' Interest in Further Training on Lean Construction Principles for Waste Reduction and Environmental Sustainability

Table 6: Interest in Further Lean Construction Training for Environmental Waste Management and Sustainability

Level of Interest	Frequency	Percentage (%)
Very High	82	49.4
High	48	28.9
Moderate	30	18.1
Low	5	3.0
Very Low	1	0.6
Total	166	100

The data shown in Table 6 indicates that 49.4% of respondents have a very high interest in further lean construction training, with 28.9% expressing high interest. Moderate interest is reported by 18.1%, while only 3.0% show low interest and 0.6% express very low interest. This

indicates strong overall enthusiasm for enhancing lean construction knowledge and its impact on environmental sustainability.

Descriptive and Factor Analysis

Table 7: Kaiser Meyer Olkin Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.963
Bartlett's Test of Sphericity	Approx. Chi-Square	4259.202
	Df	190
	Sig.	.000

Source: SPSS Computation 2024

The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy is 0.963, indicating an excellent level of sampling adequacy for factor analysis. Bartlett's Test of Sphericity shows a chi-square value of 4745.968 with 190 degrees of

freedom and a significance level of 0.001. This result signifies that the correlations among the variables are significantly different from zero, validating the factorability of the data.

Types of Construction Waste Generated on Construction Sites

Table 8: Types of Wastes Identified by Respondents

Variable	Mean	Std. Deviation	Variance	RII (3 S.F)	Rank
Operational Waste [Poor coordination between trades]	3.922	1.246	1.551	0.784	1 st
Operational Waste [Poor communication]	3.819	1.192	1.422	0.764	2 nd
Operational Waste [Rework, variation and negligence]	3.783	1.231	1.516	0.757	3 rd
Procurement [No take back schemes]	3.771	1.189	1.414	0.754	4 th
Handling [Inappropriate storage]	3.747	1.204	1.451	0.749	5 th
Operational Waste [Unskilled labor]	3.729	1.188	1.411	0.746	6 th
Procurement [Poor advice from suppliers]	3.711	1.270	1.613	0.742	7 th
Procurement [Poor supply chain management]	3.711	1.221	1.492	0.742	7 th
Operational Waste [Inclement weather]	3.693	1.214	1.475	0.739	9 th
Handling [Damage due to transportation]	3.693	1.315	1.729	0.739	9 th
Procurement [Delivery method]	3.693	1.212	1.469	0.739	9 th
Handling [Poor product knowledge]	3.675	1.212	1.469	0.735	12 th
Procurement [Purchase of inappropriate materials]	3.669	1.252	1.568	0.734	13 th
Culture [Lack of support from senior management]	3.645	1.236	1.527	0.729	14 th
Culture [Lack of incentives]	3.645	1.181	1.394	0.729	14 th
Handling [Inappropriate handling]	3.645	1.246	1.552	0.729	14 th
Procurement [Delivery schedule]	3.645	1.216	1.479	0.729	14 th
Procurement [Poor quality materials]	3.627	1.286	1.654	0.725	18 th
Culture [Lack of awareness]	3.620	1.360	1.849	0.724	19 th
Culture [Lack of training]	3.620	1.333	1.849	0.724	19 th

As seen in Table 8 above, the analysis ranks various operational challenges based on their Relative Importance Index (RII), with Poor coordination between trades identified as the most significant factor (RII = 0.784). This highlights the critical nature of effective collaboration among trades in minimizing operational waste. Following closely are Poor communication and Rework, variation, and negligence, with

RIIs of 0.764 and 0.757, respectively. These findings indicate that communication issues and project rework significantly impact overall operational efficiency.

Procurement-related factors, such as No take back schemes and Purchase of inappropriate materials, rank 4th and 13th with RIIs of 0.754 and 0.734, respectively. This suggests that ineffective procurement practices also contribute to

operational inefficiencies. Furthermore, the presence of multiple factors tied for 7th rank indicates a notable concern regarding Poor advice from suppliers and Poor supply chain management, both with an RII of 0.742, underlining the importance of sound supplier relationships and effective supply chain strategies.

Cultural factors, while lower in the overall ranking, still play a vital role, particularly regarding Lack of support from senior management and Lack of incentives, both tied at 14th rank with an RII of 0.729. This highlights the need for organizational support and motivation for employees to enhance operational performance. Factors related to Lack of awareness and Lack of training are also concerning, ranking 19th with an RII of 0.724, suggesting that improving employee knowledge and skills could lead to better management of operational challenges.

The finding that poor coordination between trades is the highest-ranked waste-generating factor is consistent with (Oyebanjo et al., 2023), who identified operational factors — including material handling and process inefficiencies — as primary drivers of material wastage on Lagos construction

sites, with wastage estimated at 18–25%. Similarly, the emphasis on procurement-related factors (no take-back schemes, poor supply chain management) aligns with (Aboginiye et al., 2021), who reported that existing construction and demolition waste management practices in Lagos were insufficiently sustainable, partly due to weak procurement controls. Internationally, these findings echo those of (Bajjou & Chafi, 2020), who identified operational and process-related factors as primary contributors to waste in Lean Construction projects. The cultural factors identified in the present study (lack of awareness, lack of training, limited senior management support) mirror findings from (Akinradewo et al., 2020), where organizational culture was shown to be a persistent barrier to Lean Construction adoption in developing countries. Collectively, these comparisons suggest that the waste-generation factors identified in this study are not idiosyncratic to Lagos but reflect broader patterns reported across both developed and developing construction sectors.

Potential Benefits of Lean Construction Management for Waste Reduction, Resource Optimization, Project Performance, and Environmental Sustainability

Table 9: Perceived benefits of Lean Construction Management

Variable	Factor Loading	Mean Value	Standard Deviation	RII (3 S.F)	Rank based on RII
Sustainability in construction	0.945	3.958	1.240	0.791	1 st
Substantial financial benefits	0.955	3.940	1.192	0.788	2 nd
Eliminating waste	0.947	3.922	1.137	0.784	3.5 th
Optimizing resource utilization	0.946	3.922	1.274	0.784	3.5 th
Safety Improvement	0.952	3.904	1.327	0.780	5 th
Improve schedule performance	0.947	3.898	1.207	0.779	6 th
Quality Improvement	0.939	3.874	1.229	0.775	7 th
Increased productivity	0.948	3.874	1.262	0.774	8 th
Rework minimization	0.815	3.849	1.244	0.769	9 th
Cost reduction	0.941	3.819	1.206	0.763	10 th

Note: A single factor was extracted, explaining 89.03% of the total variance (eigenvalue = 8.903).

Table 9 presents the descriptive statistics, RII, and factor loadings for the 10 benefit items. "Sustainability in construction" emerged as the most significant perceived benefit (RII = 0.791), followed by "Substantial financial benefits" (0.788) and "Eliminating waste" (0.784). Exploratory Factor Analysis extracted a single factor with an

eigenvalue of 8.903, explaining 89.03% of the total variance (KMO = 0.918; Bartlett's $\chi^2 = 3490.775$, $df = 45$, $p < 0.001$). All 10 items loaded above 0.91, indicating that respondents perceived the benefits of Lean Construction as a unified construct.

Strategies for Promoting the Adoption of Lean Construction Management Principles for Waste Reduction and Environmental Sustainability among Construction Firms and Stakeholders

Table 10: Strategies for reducing Construction Waste through Lean Construction Management

Variable	Factor Loading	Mean Value	Standard Deviation	RII	Rank based on RII
Value Stream Mapping	0.922	3.970	1.157	0.793	1 st
Continuous Improvement	0.939	3.964	1.170	0.792	2 nd
Technology Integration	0.904	3.940	1.137	0.787	3.5 th
Collaboration and Communication	0.924	3.940	1.158	0.787	3.5 th
Standardization of Processes	0.919	3.934	1.140	0.787	5 th
Training and Development	0.932	3.934	1.140	0.786	6.5 th
Waste Reduction	0.923	3.922	1.201	0.784	6.5 th
Root Cause Analysis	0.931	3.904	1.119	0.780	8 th
Just-In-Time Delivery	0.920	3.855	1.201	0.771	9 th
Prefabrication and modular construction	0.914	3.813	1.1578	0.762	10 th

Table 10 illustrates the descriptive statistics, RII, and factor loadings for the 10 strategy items. "Value Stream Mapping" was perceived as the most critical strategy (RII = 0.793), followed by "Continuous Improvement" (0.792). Exploratory

Factor Analysis extracted a single factor with an eigenvalue of 8.513, explaining 85.13% of the total variance (KMO = 0.931; Bartlett's $\chi^2 = 2950.027$, $df = 45$, $p < 0.001$). All 10 items loaded above 0.90.

EFA Summary

Table 11: EFA results

Construct	No. of Items	KMO	Bartlett's χ^2	df	p	Eigen Value	% Variance	No of Factors
Waste Types	20	0.963	4745.968	190	<0.001	14.71	73.56%	1
Benefits	10	0.918	3490.775	45	<0.001	8.903	89.03%	1
Strategies	10	0.931	2950.027	45	<0.001	8.513	85.13%	1

Limitations and Nonresponse Bias

This study has several limitations that should be considered when interpreting the findings. First, the 44.74% response proportion raises the possibility of nonresponse bias. The demographic profile of respondents predominantly aged 21–30, holding Bachelor's degrees or higher, and employed across small, medium, and large-scale firms broadly reflects the registered professional population in Lagos State, suggesting no systematic bias in the achieved sample. However, nonrespondents may hold different views, and findings should be interpreted with this in mind (Baruch & Holtom, 2008).

Second, the findings are based on self-reported perceptions rather than objectively measured waste quantities, so the reported waste-generating factors may not fully reflect actual site conditions. Third, the cross-sectional design limits causal inference; the associations reported cannot be interpreted as causal effects. Fourth, the study was limited to Lagos State and may not generalize to other Nigerian states or construction contexts. Fifth, the unidimensional factor structures identified in the EFA mean that the four thematic categories (operational, procurement, handling, cultural) remain descriptive groupings rather than empirically distinct dimensions in this sample.

CONCLUSION

This study examined the awareness, adoption, perceived benefits, and factors influencing the application of Lean Construction Management (LCM) among construction professionals in Lagos State, Nigeria. Findings revealed generally high awareness of Lean Construction, with 30.1% of respondents reporting very high awareness and 33.7% moderate awareness. However, the lower proportion with formal Lean training indicates a gap between conceptual awareness and practical capability, reinforcing the importance of structured education and training in supporting effective Lean implementation (Salem et al., 2006; Alarcón, 1997).

EFA confirmed a unidimensional structure for each construct, with single factors explaining 73.56% of the variance in Waste Types, 89.03% in Benefits, and 85.13% in Strategies. These values represent statistical variance explained within each construct and not percentages of waste eliminated or productivity improvement. The findings therefore reflect respondents' perceptions of common underlying dimensions rather than objectively measured waste reduction. This aligns with Lean Construction's emphasis on identifying and eliminating non-value-adding activities to improve workflow efficiency (Koskela, 1992; Ballard & Howell, 2003). Given the cross-sectional and self-reported nature of the data, the findings indicate statistical associations rather than causal impacts.

Training and development, continuous improvement, root cause analysis, and Value Stream Mapping (VSM) emerged as key strategies for Lean adoption. These approaches support the identification of process inefficiencies and improved resource utilization (Rother & Shook, 2003; Liker, 2004). Addressing operational inefficiencies may also help prevent

unnecessary material consumption and construction waste at its source.

From an environmental perspective, Lean Construction has potential to complement waste-management efforts through waste prevention and resource efficiency. By reducing material waste, rework, excess inventory, and other non-value-adding activities, Lean practices can support more resource-efficient construction and broader sustainable development objectives, including SDG 12 (United Nations, 2015).

Overall, the study concludes that LCM provides a practical framework for addressing construction waste at the point of generation while improving resource efficiency and project performance. Although environmental waste-management practices were not directly measured, the identified waste-generating factors highlight areas where Lean principles may support waste prevention and environmentally responsible construction practices in Lagos State.

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