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LEAN CONSTRUCTION AND WASTE MANAGEMENT ON BUILDING SITES IN KENYA – AN ASSESSMENT OF THE EFFECTIVENESS OF LEAN PRACTICES IN WASTE REDUCTION

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Abstract: The construction industry is known to grow rapidly in the global landscape, and it plays a pivotal role in Kenya's economic growth. Yet, it faces persistent challenges related to material wastage, inefficiencies, and environmental degradation. This paper covers the effectiveness of lean construction practices as a strategic approach to managing waste on building sites, using Nairobi City County as a case study. Lean construction, adapted from lean manufacturing, emphasizes value creation, waste elimination, and continuous improvement. Despite its global success in enhancing efficiency and sustainability, its adoption in Kenya remains limited. The study employed a mixed-methods approach, combining quantitative data from structured questionnaires and qualitative insights from interviews and observation checklists. Key findings revealed that while awareness of lean practices was moderate, their implementation remained low, hindered by resistance to change, limited training, and weak regulatory support. Nonetheless, lean practices such as the Last Planner System, 5S site organization, and Just-in-Time delivery have been shown to improve material flow, reduce delays, and enhance productivity when applied. The study concludes that lean construction practices offer a viable solution to Nairobi's construction waste problem. The findings contribute to the discourse on sustainable construction in Kenya and provide a framework that can be adapted by other urban centres across Africa facing similar challenges.

Key words: **Awareness, Building sites, Construction waste, Construction, Effectiveness, Waste management, Lean construction practices, Nairobi city county, Sustainable building.**

I. INTRODUCTION

The construction industry signifies a fundamental part that contributes substantially to the economic growth of the world, consequently, contributing to a significant part of the worldwide GDP (Gross Domestic Product) (Arleroth et al., 2011). Additionally, the construction industry over time has played a pivotal role in the socio-economic development of nations through the creation of infrastructure, employment generation, and stimulating economic growth. However, the sector is fraught with significant challenges, including inefficiencies, high levels of waste, and environmental impacts. Globally, the construction sector accounts for approximately 25–30% of total solid waste (Kibert, 2016). In Africa, the construction industry is growing, with urbanization, population growth, and infrastructural development needs being key drivers. However, the industry faces challenges such as resource inefficiency, lack of skilled labour, and high levels of material waste (Olanrewaju et al., 2020). Despite these challenges, the implementation of lean construction practices is gradually gaining traction in Africa. In urban centres like Nairobi City County, the inefficiency of conventional building practices has led to rampant material losses, delays, and environmental degradation. The construction sector in Nairobi City County faces multifaceted issues, including inadequate infrastructure, fragmented supply chains, and inefficient project delivery processes (Kamau, 2021). These challenges contribute to the generation of substantial waste throughout the construction lifecycle, encompassing material waste, time waste, and resource inefficiencies.

Lean Construction (LC), derived from the Toyota Production System, offers a value-focused approach to construction project delivery by eliminating non-value-adding activities and minimizing waste (Koskela, 1992; Sacks et al., 2020). While lean construction has proven effective globally in enhancing value and reducing waste, its uptake in Nairobi remains limited and sporadic. Prior studies (Mwangi & Kamau, 2019; Ngao, 2021) have largely centred on lean manufacturing and how it can increase competitiveness and efficiency in the manufacturing sector, leaving a gap in construction-specific research (Mwaniki & Kinuthia, 2019).

This study evaluates the effectiveness of lean construction practices in managing construction waste within Nairobi's building sector. It aims to contribute empirical evidence from Kenya's rapidly growing urban environment, where lean adoption is nascent but promising.

II. Literature Review

The study was anchored on lean production theory whose foundation commenced with the introduction of Toyota Production System (TPS) spearheaded by Taiichi Ohno of Toyota Motor Company (Ohno, 1988). It can be viewed as a manufacturing philosophy that aims at reducing the input to maximize the output. Over time, this has been indicated by minimizing waste, production time, production inventory and materials to provide value to the customer (Womack & Jones, 1996). Secondly, the research is anchored on Lean construction theory whose foundation was formed through the proposition of the transformation–flow–value (TFV) theory by Koskela (1992) and the development of the lean project delivery system by Ballard (2003). TFV refers to the conceptualization of the production process through three key elements, which are transformation that is, production of inputs into outputs; flow which is movement that is reliable and continuous; and value, that is, what the customer needs and pays for it (Ajayi et al., 2019; Nguyen & Arkhavian, 2019;). Lean project delivery system, according to Ballard and Howell (2023), links five phases of the lifecycle, which are project definition, lean design, lean supply, lean assembly, and use. Lastly, the study was also guided by balance theory of recycling advocated by Wong and Yip (2002), which encourages the adoption of the idea of reduction of wastes through clean work spaces, proper site organization and management, and the collection, separation and segregation pf construction waste.

According to the Lean Construction Institute [LCI], Lean Construction is a philosophy that is geared towards the management of construction productions with its main objective being to reduce or eliminate the activities that do not add value to the project and optimize the activities that do. Therefore, its main focus is on creating specific tools applied to the project execution process and a good system of production that minimizes waste (Bajjou & Chafi, 2020; Lean Construction Institute, n.d.; Marhani et al., 2019; Garcés & Peña, 2023). Lean management philosophy has proven effective in manufacturing, particularly in the automotive industry. Lean manufacturing production systems are mostly derived from the Japanese manufacturing industry, particularly the Toyota Production System (TPS). Therefore, the identification of the major particularities and similarities between manufacturing sector and construction sector is a critical part of understanding how the techniques of lean approach can be applied in the construction industry successfully (Bajjou et al.,2017). This can lead us to the conclusion that the adoption of Lean manufacturing principles in construction is an innovative approach that focuses on managing and enhancing construction processes by minimizing costs and maximizing value (Howell et al., 2020).

Lean construction principles are rooted in the Toyota Production System, which emphasizes the elimination of waste (muda), continuous improvement (kaizen), and maximizing value for the customer (Womack & Jones, 1996). These core principles of Lean Construction serve as the foundation for implementing Lean practices and achieving improved project efficiency and value. These principles guide construction professionals in identifying and eliminating waste, optimizing processes, and fostering collaboration (Jurado et al., 2021; Liker et al, 2018; Penny et al, 2020). These principles have given rise to practices through their applications in the construction industry.

Lean Construction practices are derived from these principles and have been adopted globally with Lean Construction Practices such as Value Stream Mapping (VSM), Just-in-Time (JIT), Last Planner system and the 5S (Sort, Set in order, Shine, Sustain, and Standardize) methodology have demonstrated measurable impacts on project performance by streamlining the construction process, enhancing efficiency and most importantly reducing waste. (Ballard & Tommelein, 2021; Aziz & Hafez, 2019). In the Kenyan context, studies have focused primarily on material waste without exploring process-oriented inefficiencies (Nganga, 2020). This paper builds on regional studies by examining the operational effectiveness of Lean Construction tools in local projects, using Nairobi as a microcosm for urban African construction.

One of the measures of the effectiveness of lean construction practices is the reduction of material waste through improved planning and inventory control. Techniques such as JIT delivery help in ensuring that materials arrive precisely when needed, therefore avoiding over-ordering, material spoilage, and losses due to poor storage which are types of lean as previously identified. Standardization and modular design also contribute to minimizing off-cuts and excess material use (Ballard & Tommelein, 2021). Lean practices have also contributed to enhanced workflow efficiency by eliminating delays and optimizing resource use through the Last Planner system, fostering early stakeholder collaboration and value engineering, which helps mitigate design related waste.

III. RESEARCH METHODOLOGY

A mixed-methods approach, combining both quantitative and qualitative research methods was used to provide a comprehensive understanding of the impact of lean construction on waste reduction. The study targeted National Construction Authority (NCA) registered contractors in Nairobi City County, specifically categories NCA1, NCA2 and NCA3. A structured questionnaire captured quantitative data, while interview guides and observation checklists provided qualitative insights. Quantitative data were analyzed using SPSS for descriptive statistics (means, medians, modes, standard deviations, and frequency distributions) and inferential statistics including ANOVA, Pearson's correlation, and chi-square tests. Regression analysis measured the relationship between lean construction practices and waste reduction effectiveness. Qualitative data were analyzed thematically using NVivo, identifying recurring themes related to benefits, challenges, and application of lean practices.

3.1 Population and Sample

The study was carried out within the Nairobi City county, Kenya which has the capital city of Kenya and serves as the economic hub of the country. A stratified sampling method based on Kenya's National Construction Authority (NCA) classification of construction companies was applied. The top three categories were picked due to the value of projects allowable for each category as shown below:

Table 3.1: Proportional distribution of population

NCA Category	Value Limit Of Contractors
NCA 1	Unlimited
NCA 2	Up to 500 Million
NCA 3	Up to 300 Million

Source: National Construction Authority, 2025

3.2 Data and Sources of Data

Data was collected through structured questionnaires and interviews to key stakeholders such as project managers, site supervisors, site architects, quantity surveyors and site engineers from construction companies within Nairobi city county; as well as observation checklists to construction sites selected purposively by the Author.

3.3 Conceptual framework

In order to understand the measure to which lean construction practices effected waste management practices, determined the effectiveness of lean construction practices in waste management. In order to measure this a conceptual framework where, the independent variables were based on the lean practices as identified in the literature review, whereas the dependent variable were based on the waste management practices such as waste reduction and/ or minimization, waste elimination as well as resource utilization which encompasses both recycling and re-use of materials, was established as shown below:

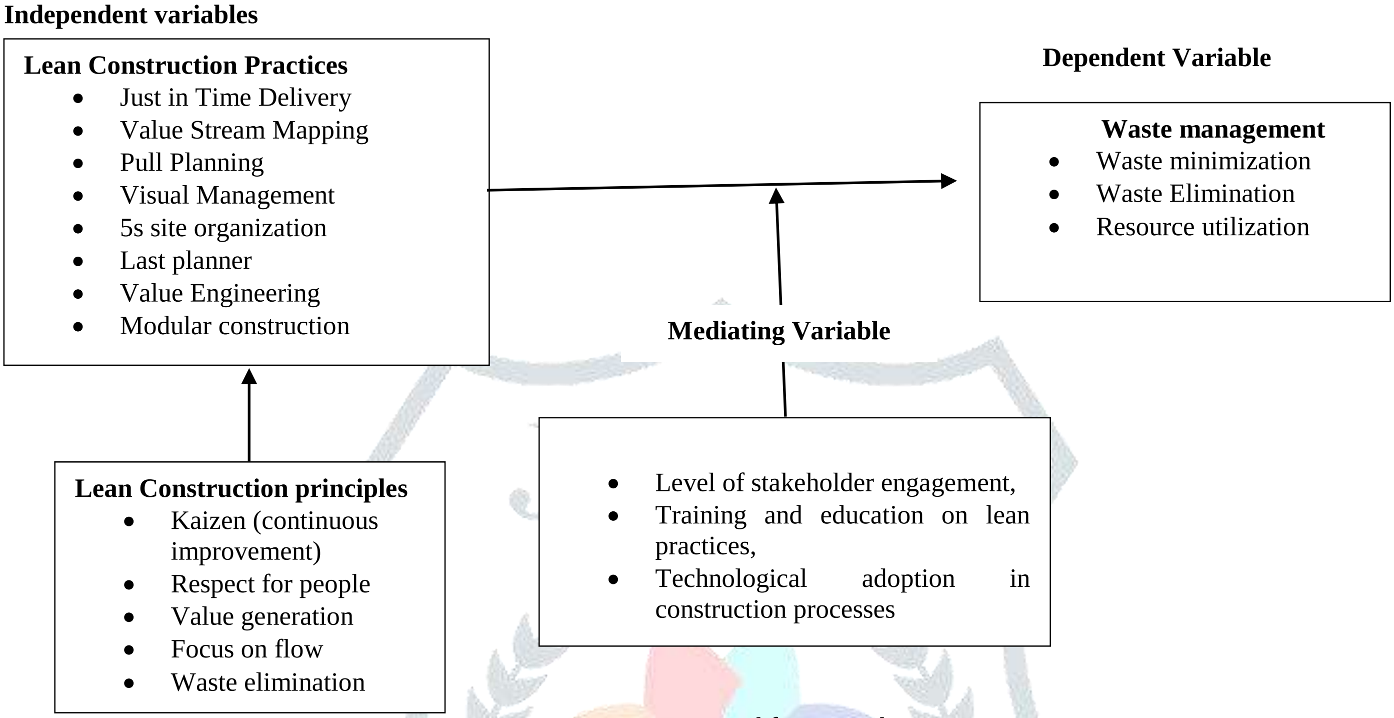

Figure 2.1: Conceptual frame work

Source: Author, 2024

3.4 Statistical tools and econometric models

A linear regression model was used to establish the causal relationship between lean practices and waste management and assess the effectiveness of individual lean practices on waste management factors. The following formulae were used in making these assessments:

$$Y = mX + b$$

Where: Y is the response (dependent) variable,
X is the predictor (independent) variable,
m is the estimated slope, and
b is the estimated intercept.

Additionally, Pearson correlation coefficients were computed to assess the relationship between these individual lean construction practices and waste reduction performance and a one-way ANOVA was also conducted to determine whether there was a statistically significant difference in waste management effectiveness based on the level of lean practice implementation. The calculations were done using SPSS software.

3.4.1 Descriptive Statistics

The data collected from interviews and observation checklists was presented on nominal scales whereas the data collected from survey questionnaires was presented on ordinal scales to establish the number of construction firms implementing lean construction and the building sites on which they have been applied. Frequency distribution tables, percentages, bar charts, and pie charts were also used to further present the data for ease of data interpretation.

To ensure content validity, the questionnaire was reviewed by academic supervisors and industry experts. Additionally, it was pre-tested on contractors not included in the final sample through a pilot study. Feedback from the pilot was used to revise ambiguous items and improve clarity. The reliability of the questionnaire was tested using Cronbach's Alpha**.** A threshold value of **0.7** was used to determine internal consistency, in line with standard research practices. Additionally, the observation checklists were used to ensure consistency and objectivity of the data collected, hence validating survey data.

IV. RESULTS AND DISCUSSION

4.1 Results of Descriptive Statics of Study Variables

Table 4.1: Effectiveness of lean construction practices

	No. of Respondents	Percentage
Kaizen	22	16.67
Collaborative planning and communication (LPS)	24	18.18
Value Stream Mapping	7	5.30
5S Methodology	46	34.85
Just in time Delivery	33	25.00
Total	132	100

Source: Study survey, 2025

Table 4.1 shows the perceived effectiveness of lean construction practices in waste management. 5S (Sort, Set in order, Shine, Sustain, and Standardize) site organization was leading rated at 35%, followed by JIT delivery and Collaborative planning and communication (Last Planner System) rated at 25% and 18% respectively. Additionally, Table 4.2 below shows Pearson correlation coefficients were computed to assess the relationship between these individual lean construction practices and waste reduction performance.

Table 4.2: Pearson correlation coefficient

Lean Tool	Pearson r	Sig. (2-tailed)	Interpretation
JIT Delivery	0.61	< 0.01	Strong positive correlation
5S Organization	0.57	< 0.01	Moderate to strong correlation
Kaizen	0.68	< 0.01	Strong positive correlation
Last Planner System	0.49	< 0.05	Moderate correlation

Source: Author, 2025

All correlations are significant at $p < 0.05$. The strongest association was observed between value engineering and waste reduction (r = 0.68), indicating that improved planning and design integration leads to reduced material loss. These findings align with Mwangi et al. (2021) and Olanrewaju & Abdul-Aziz (2020), who reported positive outcomes from lean tool implementation. According to studies done by Aziz & Hafez (2019) and Prashanth et al. (2023), tools like value stream mapping, Last planner system, and 5S site organization promoted better site organization and consequently reduced inefficiencies. Globally, a 30% reduction in rework through LPS was witnessed as reported by Ballard & Howell (2020).

Table 4.3: One-way ANOVA by lean implementation

Source of Variation	SS	df	MS	F	Sig. (p)
Between Groups	12.78	2	6.39	5.63	0.004*
Within Groups	128.45	129	0.99		
Total	141.23	131			

*p < 0.05 indicates statistical significance.

Source: Author, 2025

Table 4.3 shows a one-way ANOVA conducted (formulae in appendix IX) to determine whether there is a statistically significant difference in waste management effectiveness based on the level of lean practice implementation. The ANOVA results indicate a statistically significant difference (p = 0.004) in waste management effectiveness across the three groups. Projects with high implementation of lean practices showed significantly better waste management outcomes. This supports studies by Sarhan & Fox (2020) and Kamau (2021), which demonstrated similar impacts of lean implementation levels.

Linear regression analysis was used to examine the relationship between the implementation of lean construction practices (independent variables) and the level of waste management (dependent variable) on construction sites in Nairobi City County. This analysis aimed to statistically validate the theorised relationships outlined in the conceptual framework. The conceptual framework of this study theorised that lean construction practices are critical drivers of construction waste management which is measured through Waste elimination, waste reduction and resource utilization. These variables were operationalized and used as predictors in the linear regression model, with waste reduction serving as the dependent outcome.

Table 4.4 shows the linear regression analysis between lean practices and waste reduction. The findings of the analysis show that Lean practices such as optimized site organization (β = .299, p < .001), prefabrication and modular construction (β = .282, p = .001), and just-in-time delivery (β = .501, p < .001) were found to be significant predictors of waste reduction.

Table 4.4: Regression analysis of waste reduction and lean practices

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	1.109	.109		10.147	<.001	.892	1.325		
	Value_Stream_Mapping	.044	.053	.052	.844	.400	-.060	.149	.104	9.656
	Optimized_Site_Organization_5S	.200	.049	.299	4.037	<.001	.102	.297	.071	14.159
	Kanban	.190	.076	.266	2.509	.013	.040	.340	.034	29.095
	Pull_Planning	-.067	.052	-.098	-1.292	.199	-.170	.036	.067	14.873
	Kaizen	-.159	.060	-.160	-2.670	.009	-.277	-.041	.108	9.259
	Visual_Management	-.070	.068	-.085	-1.030	.305	-.203	.064	.056	17.752
	JIT_Delivery	.478	.065	.501	7.312	<.001	.349	.608	.083	12.105
	LPS	.002	.062	.002	.026	.980	-.121	.124	.070	14.323
	Prefabrication_and_Modular_Construction	.215	.057	.282	3.800	<.001	.103	.327	.070	14.263
	Value_Engineering	-.050	.062	-.057	-.815	.417	-.172	.072	.079	12.725

a. Dependent Variable: Overall Measure of effectiveness of Lean Practices on waste reduction

Source: Author, 2025

Similarly, Table 4.5 and table 4.6 show that prefabrication had the strongest positive impact on waste elimination (β = .488, p < .001) and resource utilization (β = .630, p < .001), demonstrating its broad applicability and effectiveness. Additionally, optimized site organization (5S) which demonstrated showed a positive impact on waste elimination (β = .304, p < .001) and resource utilization (β = .433, p < .001); with LPS having a significant impact in waste elimination (β = .320, p < .001) and moderate impact on resource utilization (β = .210, p < .001). However, practices such as Kaizen, Value Stream Mapping, and Kanban yielded negative or insignificant results, suggesting potential misalignment with the current construction context in Nairobi. These results underscore the importance of context-specific implementation and suggest that while lean principles are theoretically sound, their practical effectiveness depends on factors such as training, enforcement, and regulatory integration.

Table 4.5: Regression analysis of waste elimination and lean practices

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	-.597	.159		-3.759	<.001	-.912	-.283		
	Value_Stream_Mapping	-.244	.077	-.206	-3.194	.002	-.396	-.093	.104	9.656
	Optimized_Site_Organization_5S	.279	.072	.304	3.884	<.001	.137	.422	.071	14.159
	Kanban	-.391	.110	-.397	-3.540	<.001	-.609	-.172	.034	29.095
	Pull_Planning	.327	.075	.348	4.340	<.001	.178	.476	.067	14.873
	Kaizen	.556	.087	.405	6.414	<.001	.384	.727	.108	9.259
	Visual_Management	-.364	.098	-.324	-3.704	<.001	-.559	-.169	.056	17.752
	JIT_Delivery	.151	.095	.114	1.583	.116	-.038	.339	.083	12.105
	LPS	.366	.090	.320	4.074	<.001	.188	.544	.070	14.323
	Prefabrication_and_Modular_Construction	.512	.082	.488	6.223	<.001	.349	.675	.070	14.263
	Value_Engineering	-.099	.090	-.082	-1.109	.269	-.277	.078	.079	12.725

a. Dependent Variable: Waste_Elimination

Source: Author, 2025

Table 4.6: Regression analysis of resource utilization and lean practices

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	-.122	.147		-.832	.407	-.412	.168		
	Value_Stream_Mapping	-.393	.071	-.310	-5.564	<.001	-.533	-.253	.104	9.656
	Optimized_Site_Organization_5S	.426	.066	.433	6.418	<.001	.295	.557	.071	14.159
	Kanban	-.355	.102	-.337	-3.484	<.001	-.556	-.153	.034	29.095
	Pull_Planning	.310	.070	.309	4.465	<.001	.173	.448	.067	14.873
	Kaizen	.272	.080	.185	3.398	<.001	.113	.430	.108	9.259
	Visual_Management	.019	.091	.016	.205	.838	-.161	.198	.056	17.752
	JIT_Delivery	-.014	.088	-.010	-.154	.878	-.187	.160	.083	12.105
	LPS	.257	.083	.210	3.099	.002	.093	.421	.070	14.323
	Prefabrication_and_Modular_Construction	.706	.076	.630	9.293	<.001	.555	.856	.070	14.263
	Value_Engineering	-.233	.083	-.181	-2.824	.006	-.397	-.070	.079	12.725

a. Dependent Variable: Resource_Utilization

Source: Author, 2025

The results of the linear regression analysis affirm the conceptual framework of the study, which proposed that the application of lean construction practices positively influences waste reduction, waste elimination, and resource utilization. The findings empirically support the study's conceptual framework, validating the theoretical assertion that lean construction practices are instrumental in achieving waste reduction. The positive and significant regression coefficients for JIT, 5S, and prefabrication and modular construction across the three variables for waste management, confirm their direct relationship with waste management. However, the non-significant impact of Continuous Improvement highlights a potential gap in consistent application or may indicate challenges in sustaining lean culture on Kenyan construction sites. These results are consistent with Ballard and Howell (2003), who found that JIT and 5S significantly reduce site waste through process optimization and improved material flow. Similar findings were observed in South Africa by Sarhan and Fox (2020), reinforcing the broader applicability of lean principles in developing contexts. However, the limited impact of Continuous Improvement contrasts with Ogunbayo et al. (2021), who emphasized its role in sustaining lean gains, this suggests a possible difference in local implementation capacity or cultural readiness.

V. Conclusion

This study demonstrates that lean construction practices can significantly enhance waste management in Nairobi City County. Adoption of practices such as optimized site organization, prefabrication, and the Last Planner System can lead to measurable improvements in project efficiency and sustainability.

VI. Recommendations

1. Integrate lean construction principles into National Construction Authority and NEMA regulations.
2. Provide targeted training and capacity-building programs for contractors.
3. Encourage lean adoption through procurement incentives such as tax rebates or performance bonuses.
4. Develop localized lean guidelines tailored to Kenya's construction industry.
5. Foster collaboration among industry stakeholders to share best practices.

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