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Investigating the Effect of Innovative Construction Waste Management Practices on the Performance of Building Projects in Lagos State, Nigeria

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ABSTRACT

The construction sector in Lagos State, Nigeria, faces significant challenges due to waste generation, impacting both the environment and project efficiency. Recognizing the urgency to address these issues, there has been a growing interest in identifying and implementing effective construction waste management practices to enhance building project performance in the region. Despite existing literature recognizing the significance of innovation in waste management, there remains a notable gap in comprehending the precise impact of these practices on project outcomes specifically within Lagos State. Therefore, this study seeks to fill this gap by investigating the influence of Innovative Construction Waste Management Practices (ICWMPs) on building project performance in the region. Data were analysed using Partial Least Square in Structural Equation Modelling (PLS-SEM) analysis due to its suitability for examining multi-dimensional indicators. Findings reveal significant relationships between ICWMPs specifically industry policy (DIP), innovative materials and equipment (DME), and innovative manpower approach (DMP), and various project performance metrics such as cost, quality, and time. Industry policy emerged as the most influential factor, significantly impacting cost performance (β=0.526, T=4.984). Additionally, innovative materials and equipment (β=0.351, SE= 0.044) and innovative manpower approach (β=0.170, T=2.755) demonstrated significant relationships, emphasizing their importance in delivering quality work. The study recommends prioritizing adherence to industry policy, efficient innovative materials, equipment management, and strategic innovative manpower approach for construction industry stakeholders in Lagos State in order to optimize project performance in the region. These findings enhance our understanding of the interplay between waste management practices and project performance and provide valuable insights for promoting sustainable development within the construction sector.

Keywords:
Construction industry; Waste management practices; Partial least squares; Structural equation modelling; Lagos State.

INTRODUCTION

The construction sector's indispensable role in economic growth is coupled with the unintended consequence of substantial construction waste generation (Yu *et al.*, 2021). This waste not only poses environmental challenges but also imposes financial burdens on contractors, project costs, timelines, and overall efficiency (Wang *et al.*, 2019). Lagos State, as a hub of urban development and infrastructural growth, exemplifies the intricate relationship among construction waste management practices, innovation adoption, and project performance. The existing literature acknowledges the importance of innovative practices in enhancing waste management practices (Kolaventi & Prasad, 2014), yet there is a notable lack of a comprehensive framework tailored to the unique circumstances of Lagos State's construction industry. The absence of a holistic understanding of how construction waste management practices, innovative practices, and project performance intertwine in Lagos State hampers the development of sustainable waste reduction solutions. While various studies independently explored the aspects of waste management practices (Tam & Lu, 2016; Aboginije *et al.*, 2021; Gaeta *et al.*, 2021; Crawford & Bryce, 2013; Rosli *et al.*, 2023) innovative practices (Udawatta *et al.*, 2015; Osmani & Villoria-Sáez, 2019; Tambovceva *et al.*, 2020) and project outcomes (Firmawan *et al.*, 2012; Hamad *et al.*, 2021), there is a noticeable gap in comprehensive analyses that quantitatively assess the relationships between these facets. This research aims to address this gap by investigating the effect of innovative construction waste management practices on building project performance in Lagos State. The dearth of empirical research impedes the identification and evaluation of innovative measures that can enhance waste reduction solutions. The study seeks to provide a nuanced understanding of the nexus between construction waste management practices, innovative practices, and project performance, offering actionable insights for policymakers and industry stakeholders in Lagos State, Nigeria.

LITERATURE REVIEW

Implementing innovative waste management (WM) measures in the construction industry offers various advantages encompassing economic, quality, and sustainability benefits (Wang *et al.*, 2023). Contractors, as emphasized by Al-Raqeb *et al.* (2024), can significantly reduce construction costs through the implementation of waste plans. The cost benefits are derived from reductions in material purchasing costs (Jaillon *et al.*, 2009), transportation costs for materials and waste (Halvorsen & Anderson, 2023; Jaillon *et al.*, 2009), waste minimization (Aljarallah *et al.*, 2024), and waste disposal expenses, including tipping (Chen *et al.*, 2024). Apart from economic gains, innovative WM practices also yield social and environmental benefits by reducing the need for landfill space and mitigating health risks associated with waste disposal (Wilson, 2023). Additionally, the creative management of construction waste is viewed as a means to enhance productivity and safety on construction sites (Haider *et al.*, 2022). Poon *et al.* (2014) underscored the importance of focusing on WM during the planning stage of building development to minimize waste levels in building projects.

Nevertheless, Osmani *et al.* (2008) identified a challenge where architects exhibit less engagement in waste minimization due to a lack of knowledge about the causes of design waste generation and the perception that contractors bear responsibility for waste minimization. While advocating for onsite WM systems to reduce construction waste generation (Gherman *et al.*, 2023), the limitation of space on construction sites poses a constraint, requiring allocation for WM equipment, storage of construction waste, and space for processed materials (Wilson 2023; Hei *et al.*, 2024). The effectiveness of WM outcomes is also contingent upon the availability of local infrastructure for recycling (Rafiquee & Shabbiruddin, 2024).

Researchers argue for the application of lean principles to eliminate all forms of waste by refocusing on the production process and creating value through process reliability (Nowak *et al.*, 2023; Schwantz *et al.*, 2023). Prefabrication technologies are suggested as a means to fully avoid construction waste generation (Tam *et al.*, 2007), but Jaillon *et al.* (2009) revealed a 52% average waste reduction rate, highlighting that prefabrication methods, despite their advantages, cannot entirely eliminate construction waste production. The collaboration and dedication of all stakeholders are deemed essential to identify and promptly address potential waste generation sources (Alwi *et al.*, 2002, Manowong, 2012).

Implementing innovative waste management (WM) plans and assigning implementation responsibilities to designated individuals proves effective in handling construction waste within projects, as emphasized by Wilson (2023). However, ensuring effective waste management requires regular site inspections and periodic reviews of WM performance to identify additional waste reduction needs (Selomo, 2023). Researchers underscore the significance of enhancing communication in the implementation of effective WM in construction projects, advocating for clear communication channels between main contractors and subcontractors (Gavilan and Bernold, 1994).

The efficacy of WM strategies can be improved by educating supervisors and staff about waste minimization strategies, emphasizing the advantages of profit maximization, and highlighting to all staff that WM is as crucial as addressing time, cost, quality, and safety issues in construction projects, as highlighted by Saeed and Yas (2023). Yuan (2013) underscores the critical role of enhancing major project stakeholders' awareness of resource conservation and environmental protection to enhance WM performance in construction projects.

Despite the perceived advantages of training programs, there is a divergence of opinion within the construction industry. According to Lingard *et al.* (2000), while managers view training programs as effective, construction workers often consider them irrelevant. Consequently, there is a pressing need to encourage the industry to endorse appropriate waste management (WM) practices and integrate environmental considerations during the design and tendering phases (Wang *et al.*, 2019). The implementation of pertinent policies and regulations is recognized as a crucial incentive, with legislation playing a central role in motivating architects to design waste-free construction projects, as demonstrated by Osmani *et al.* (2008). Other proposed strategies for improving WM include disseminating waste indices to the public, ensuring opportunities for reuse/recycling through careful handling and storage of recyclable materials, and promoting good housekeeping (Poon *et al.*, 2004). However, McKenzie-Mohr (2011) argues that improving knowledge and changing attitudes have limited effects on behaviourial change. Yuan (2013) emphasizes the importance of developing a mature recycling market for construction products to promote recycling in construction projects. Kolaventi and Prasad (2014) categorized innovative construction waste management measures into Innovative manpower approach, Innovative materials and equipment, Construction Method, Management Practice, and Industry Policy. Drawing on this extensive literature review, the study aims to explore the feasibility of implementing these innovative WM approaches in the context of Lagos State, Nigeria. The literature review explores the multifaceted impact of implementing innovative waste management (WM) practices in the construction industry, emphasizing the potential economic, quality, and sustainability benefits. Studies underscore the cost-saving advantages achieved through innovative WM plans, encompassing reductions in material purchasing, transportation costs, waste minimization, and disposal. Additionally, the social and environmental benefits, including reduced landfill requirements and health risks associated with waste disposal, are highlighted. Challenges and gaps in the existing literature become apparent as the review addresses the limited engagement of construction professionals in waste minimization efforts, attributed to knowledge gaps and a perception that contractors bear primary responsibility. Constraints related to on-site WM, such as space limitations and reliance on local infrastructure for recycling, pose additional challenges. Conflicting views on the effectiveness of training programs in waste reduction further underscore areas requiring deeper exploration. Notably, gaps exist in literature regarding the relationship between innovative practices and construction project performance**.** The study aims to bridge these identified gaps by investigating the applicability of innovative construction waste management approaches in Lagos State, Nigeria, utilizing Partial Least Square in Structural Equation Modelling to understand the relationships between innovative WM practices and project performance in this specific context.

Project Performance in Construction Industry

Crawford and Bryce (2013) observe that a project is only successful if it comes on schedule, on budget, achieves the deliverables originally set for it and it is accepted and used by the clients for whom the project was intended. Evaluating project performance is based on projects completed on time and within the allocated budget, making sure the project contributes to the global strategy of a company or achieves customer satisfaction. Large infrastructural projects suffer from significant under-management of risk in practically all stages of the value chain and throughout the life cycle of a project as indicated by Chua *et al.* (2014).

The performance or success of a construction project with respect to buildings is measured using two categories: small and large viewpoints (Hamad *et al.*, 2021). The former is measured by time, cost and quality of completion in addition to the completion performance and safety while the latter is assessed by completion time, stakeholders' satisfaction and completion of facilities and operation (Abu Aisheh *et al.*, 2021; Hamad *et al.*, 2021). However, defining project performance has remained unclear for construction professionals; thus, numerous studies on the critical factors affecting the performance or success of construction projects have been conducted in the past years (Ramlee *et al.*, 2016; Das & Ngacho, 2017; Tayeh *et al.*, 2018; Hamad *et al.* , 2021; Abu Aisheh *et al.*, 2021). Different critical success factors (CSFs), such as safety, quality, time and scheduling, planning, resources, cost and finance, technology, environment, organisation, management, experience, size and type of previous projects, have been defined by several researchers. However, no general agreement has been identified (Ramlee *et al.*, 2016; Maliha *et al.*, 2021; Abu Aisheh *et al.*, 2021).

Hamad *et al.* (2021) classified successful construction project performance factors into five categories: project-related, project procedures, project management actions, human-related and external environmental factors. Maliha *et al.* (2021) summarised the CSFs identified by several researchers to include cost, time, quality, satisfaction, management, safety, technology, organisation, environment and resources. All researchers have agreed that cost, time and quality are important CSFs, whereas 50% of these researchers have considered management, technology, organisation and satisfaction as important CSFs. Babu and Sudhakar (2015) summarised the most important CSFs within the project life cycle as clarity of project objectives, top management support, efficiency of project manager, efficiency of project team members, detailed plan of the project activities or schedule, effective communication between client and project team members, quality of suppliers and subcontractors, client approvals, monitoring and feedback, suitable technology and communication network and troubleshooting of unexpected crisis and problems. Darwish *et al.* (2020) summarised the specific success dimensions identified by other researchers and reported that cost, time, quality, efficiency, performance and technical success factors have been excessively researched. Other factors, such as client satisfaction, safety, team creativity, knowledge and project management process, must be further explored. Al-Ashmori *et al.* (2020) defined a construction project as successfully delivered, if it satisfies the specified completion time, total cost, agreed technical specifications of the project and clients' and customers' expectations. These project success measures depend on various factors, such as client, contractor, project team, nature of the project, location and size of the project, technology to be used, contract type and risks involved (Tayeh *et al.*, 2020).

This study utilized cost, quality, and time as project performance proxies as they provide a robust framework for evaluating the effectiveness of innovative construction waste management practices. These proxies are not only relevant and measurable but also essential for understanding the holistic impact of waste management interventions on project outcomes in the context of Lagos State, Nigeria.

Gaps in Literature

The literature review provided a comprehensive understanding of the multifaceted impact of implementing innovative waste management (WM) practices in the construction industry. It highlighted the potential economic, quality, and sustainability benefits associated with such practices. These benefits include cost savings derived from reduced material purchasing, transportation costs, waste minimization, and disposal expenses, as well as social and environmental advantages such as reduced landfill requirements and mitigated health risks. Despite the evident advantages, the review also identified several challenges and gaps in the existing literature. These gaps include the limited engagement of construction professionals in waste minimization efforts, constraints related to on-site WM such as space limitations and reliance on local

Table 1: Summary of the types of waste management practices and proxies for performance found in the literature

Waste Management Practices	Author(s) and Year
Implementation of waste plans for cost reduction	Al-Raqeb *et al.* (2024)
Lean principles application for waste elimination	Nowak *et al.* (2023); Schwantz *et al.* (2023)
Onsite waste management systems	Gherman *et al.* (2023)
Training programs for waste minimization	Saeed and Yas (2023)
Integration of environmental considerations in design and tendering	Wang *et al.* (2019)
Innovative manpower approach, Innovative materials and equipment, construction method, management practice, and industry policy	Kolaventi & Prasad, (2014), Udawatta *et al.* (2015)
Policy and regulation implementation	Osmani *et al.* (2008)
Dissemination of waste indices and promoting recycling	Poon *et al.* (2004); Yuan (2013)
Prefabrication technologies	Tam *et al.* (2007); Jaillon *et al.* (2009)
Collaboration among stakeholders	Alwi *et al.* (2002); Manowong (2012)
Assigning implementation responsibilities	Wilson (2023)
Enhancing communication channels	Gavilan and Bernold (1994)

Source: Authors' Literature Review

infrastructure for recycling, conflicting views on the effectiveness of training programs, and a lack of clarity in defining project performance within the construction industry.

Moreover, while the literature extensively discusses various critical success factors (CSFs) affecting project performance, including cost, time, quality, and others, there is no general agreement on these factors. This lack of consensus indicates the need for further exploration and identification of specific success dimensions, particularly in the context of construction projects in Lagos State, Nigeria.

In this context, the research aims to bridge these identified gaps by investigating the applicability of innovative construction waste management approaches in Lagos State, Nigeria. The study focuses on understanding the relationships between innovative WM practices and project performance, specifically examining cost, quality, and time as project performance proxies. Through the utilization of Partial Least Square in Structural Equation Modelling, the study aims to provide insights into how innovative WM practices impact project performance in this specific context.

By conducting empirical analysis and examining the relationships between innovative WM practices and project performance measures, the study aims to contribute to the existing body of knowledge by providing practical insights for stakeholders in the construction industry. Ultimately, this research endeavours to inform decision-making processes and facilitate the adoption of effective waste management strategies to enhance project outcomes in Lagos State, Nigeria.

Theoretical Framework: Lean Theory

The underpinning theory for this study is the Lean Theory of Innovation. Inspired by principles from lean management and manufacturing, it emphasizes the continuous pursuit of efficiency, value creation, and elimination of waste in all aspects of an organization's operations (Mandujano *et al.*, 2016; Tafazzoli *et al.*, 2020). Rooted in the work of scholars like Jones & Womack (2016); and Womack (2006), this theory posits that innovation should focus on identifying and eliminating non-value-added activities, streamlining processes, and optimizing resource utilization. By doing so, organizations can achieve improved performance, reduced costs, and increased customer satisfaction (Mellado and Lou, 2020; Goh and Goh, 2019).

Applying the Lean Theory of Innovation to construction waste management in Lagos State involves adopting a holistic approach that seeks to minimize waste generation, optimize resource utilization, and enhance the efficiency of waste disposal and recycling processes. Construction firms can implement lean-inspired practices such as just-in-time delivery of materials, efficient procurement strategies, and optimized construction schedules to reduce waste and improve project timelines. Moreover, the adoption of digital technologies and data-driven decision-making can enable real-time monitoring and control of waste management processes (Herrera *et al.*, 2019).

The Lean Theory of Innovation suggests that lean-inspired practices in construction waste management can lead to enhanced building project performance in Lagos State. By focusing on waste reduction, efficient resource allocation, and process optimization, construction projects can achieve shorter project timelines, reduced costs, and improved overall project outcomes (Ingle & Waghmare, 2015). Additionally, the emphasis on value creation and customer satisfaction aligns with the Lean Theory's principles, contributing to the delivery of high-quality projects that meet or exceed stakeholders' expectations (Carvajal-Arango *et al.*, 2019).

Integrating the Lean Theory of Innovation into the nexus of construction waste management, and building project performance underscores the importance of embracing lean principles to drive positive change within the construction industry in Lagos State. By applying lean principles to waste management practices, the construction industry can a chieve greater efficiency, reduced waste, and improved project outcomes. This theoretical review lays the groundwork for future empirical research that explores and validates the applicability of the Lean Theory of Innovation within the context of construction waste management and project performance in Lagos State.

METHODOLOGY

The study was carried out in Lagos State, Nigeria due to the State's numerous construction organizations, and a diverse array of practitioners and specialists in the construction industry. Furthermore, Lagos, serving as the economic and commercial hub of the Nation, was selected for its abundance of completed, operational, and ongoing building projects. It distinguishes itself as one of the Nigerian States that has effectively implemented innovative techniques across various infrastructural projects. Furthermore, as one of the South West Nigerian states, Lagos has operational infrastructural development models involving crucial stakeholders from State-level Ministries, Departments, and Agencies. The study specifically targets professionals with expertise in building construction waste management projects within selected Ministries, Departments, and Agencies (MDAs) in Lagos State, Nigeria. The population comprises Engineers, Project Managers, Architects, Builders, Quantity Surveyors, and Legal practitioners. Among the MDAs, the Lagos State Ministry of Works and Infrastructure (LSMWI) has 156 professionals, the Ministry of Housing has 103, the Lagos State Development and Property Corporation (LSDPC) has 94, and the Office of Public-Private Partnerships has 73, bringing the total MDA population to 426 (Aladejebi *et al.*, 2023). Additionally, participants were selected from private building construction firms listed in the directory of the Lagos State Ministry of Housing, which encompasses 2684 firms. This study employed a probabilistic sampling technique, specifically utilizing simple random sampling to determine the sample size from the overall population. The Yamane sample size formula was applied to establish the sample size for participants from Ministries, Departments, and Agencies (MDAs). Considering a total population (N) of 426 MDAs and an acceptable error limit (e) of 0.05, the calculated sample size (n) was 207. Bowley (1926) proportional allocation formula was then utilized to distribute the sample size among various MDAs, resulting in specific sample sizes for each: Office of PPP (35), LSDPC (46), LSMH (50), and LSMWI (76). For participants from private building construction firms, Cochran's sample size formula determined a sample size of 385. Combining both participant categories, the overall sample size for the study is 592. This sampling approach ensures representation from both government MDAs and private firms. Primary data for this research was collected through a close-ended questionnaire and observations from relevant professionals involved in completed or ongoing building construction projects in the study area. To ensure the validity of the research instrument, a pre-test was conducted, and content validity was confirmed by engaging three experts. The analysis employed Partial Least Square in Structural Equation Modelling (PLS-SEM) for regression analysis. This method of statistical analysis was chosen for its suitability in examining multi-dimensional indicators. The assessment involves two steps: a) evaluating the reliability and validity of the measurement model, and b) testing the structural model and hypotheses. The analysis includes assessing individual item reliability, construct reliability, convergent validity, and discriminant validity for the measurement model. The structural model examines the sign, size, and significance of coefficients between dependent and independent variables.

Measurement of Innovative Construction Waste Management Practices (ICWMPs) and Building Project Performance

This section provides information on the measurement of variables for the objective of the study. The procedure followed the determination of the measurement model before the structural analysis was conducted. The proxies measured encompass the exogenous constructs, that is, innovative construction waste management practices. These are specific approaches implemented within the construction industry to address waste management issues in a creative and effective manner. These proxies include innovative manpower approach with 5 indicators (DMP1-5), innovative materials and equipment with 6 indicators (DME1-6), construction method with 8 indicators (DCM1-8), management practice with 6 indicators (DMT1-6), and industry policy with 8 indicators (DIP1-8); and the endogenous constructs of project performance which are cost (FCost), time (FTime), and quality (FQuality), each having four indicators as shown in Table 2 and in the appendix. All constructs and indicators were adapted from Kolaventi and Prasad, (2014), Udawatta *et al.* (2015) and Ahmad *et al.* (2021). Due to the formative model assessment, the study examined the relevance and significance of the manifest to ascertain the quality of the data collected as well as the VIF of the items. As shown in Table 2, the study reported the weights, landings of indicators with their significance and VIF to ascertain that there was no issue relating to multicollinearity. The results showed that there were twenty-eight (28) indicators relevant to their respective constructs likewise, some of the indicators were absolutely important (4), while the remaining were accepted due to their theoretical relevance (12) to their respective constructs. This was in accordance to Hair *et al.* (2022) guidelines for assessing the formative indicators. The study recalls that FCI (Estimate considers waste minimization plan) was removed from further, analysis due to non-significant weight and loading. Thus, other indicators were acceptable for further procedure in structural model as the VIFs were within the acceptable value of 5 (Adepoju *et al.*, 2023).

FINDINGS

Demographic Characteristics of Respondents

This section of the study presents the survey findings, offering insights into respondent characteristics and the primary study objectives. Remarkably, the response rate (Table 3) achieved an impressive 90.6%, surpassing the recommended significance threshold of 30-40% (Moser & Kalton, 2017).

Regarding demographics (Table 4), the construction landscape in Lagos State appears predominantly male-dominated (91.4%), raising potential considerations for gender-specific aspects in waste management practices. Notably, a considerable portion of respondents falls within the 21-30 (47.6%) age bracket, indicating a youthful workforce actively involved in construction endeavours. The diverse educational backgrounds among respondents, spanning various qualifications, underscore the necessity for nuanced waste management strategies tailored to the varied academic profiles within the industry. Examining the professional spectrum, engineers and builders emerge as prominent, constituting 43.4% and 32.7%, respectively. This distribution emphasizes the crucial roles these professional groups play in construction projects in Lagos State, highlighting the need for targeted waste management approaches aligned with their specific responsibilities. Analysis of respondents' years of experience reveals a significant proportion in the early stages of their careers, with 42.6% having less than 5 years of experience and 41.7% falling within the 5-10 years bracket.

Table 2: Relevance and Significance of ICWMPs and Performance Indicators

Path	Weight	T statistics	P values	Loadings	T statistics	P values	Reason	VIF
DCM1 -> DCM	0.308	3.530	0.000	0.752	15.798	0.000	RI	2.525
DCM2 -> DCM	0.200	2.147	0.032	0.785	15.745	0.000	RI	2.996
DCM3r -> DCM	0.049	0.779	0.436	-0.372	4.072	0.000	TR	1.975
DCM4 -> DCM	0.115	1.956	0.051	0.463	5.809	0.000	TR	2.046
DCM5 -> DCM	0.563	8.438	0.000	0.887	29.047	0.000	RI	1.852
DCM6r -> DCM	0.031	0.473	0.637	-0.418	4.955	0.000	TR	1.966
DCM7r -> DCM	0.019	0.272	0.786	-0.418	4.931	0.000	TR	2.330
DCM8 -> DCM	0.182	2.978	0.003	0.538	7.468	0.000	RI	1.715
DIP1 -> DIP	0.371	4.014	0.000	0.872	29.862	0.000	RI	3.831
DIP2 -> DIP	0.130	1.513	0.130	0.796	18.522	0.000	AI	3.389
DIP3 -> DIP	0.033	0.718	0.473	0.324	4.270	0.000	TR	1.371
DIP4 -> DIP	0.031	0.683	0.495	0.211	2.943	0.003	TR	1.218
DIP5 -> DIP	0.437	4.501	0.000	0.856	20.365	0.000	RI	1.827
DIP6 -> DIP	0.148	2.661	0.008	0.697	12.857	0.000	RI	2.005
DIP7r -> DIP	0.073	1.496	0.135	-0.445	6.187	0.000	TR	1.600
DIP8 -> DIP	0.165	2.877	0.004	0.670	11.401	0.000	RI	1.569
DME1 -> DME	0.144	1.920	0.055	0.770	19.567	0.000	AI	2.813
DME2 -> DME	0.364	4.625	0.000	0.807	21.384	0.000	RI	2.844
DME3 -> DME	0.375	5.185	0.000	0.806	19.129	0.000	RI	1.703
DME4 -> DME	0.196	4.223	0.000	0.426	6.785	0.000	RI	1.320
DME5 -> DME	0.096	1.892	0.059	0.367	5.444	0.000	TR	1.332
DME6 -> DME	0.296	4.571	0.000	0.587	8.767	0.000	RI	1.253
DMP1 -> DMP	0.482	7.793	0.000	0.711	12.205	0.000	RI	1.205
DMP2 -> DMP	0.172	2.991	0.003	0.397	5.127	0.000	RI	1.138
DMP3 -> DMP	0.278	4.226	0.000	0.763	19.194	0.000	RI	1.757
DMP4 -> DMP	0.373	5.571	0.000	0.729	13.579	0.000	RI	1.712
DMP5 -> DMP	0.211	2.814	0.005	0.492	6.521	0.000	RI	1.232
DMT1 -> DMT	0.301	4.692	0.000	0.419	5.334	0.000	RI	1.035
DMT2 -> DMT	0.327	3.335	0.001	0.667	9.043	0.000	RI	1.462
DMT3 -> DMT	0.120	1.202	0.229	0.667	10.736	0.000	AI	1.716
DMT4 -> DMT	0.597	9.168	0.000	0.850	22.533	0.000	RI	1.440
DMT5 -> DMT	0.119	1.440	0.150	0.296	2.883	0.004	TR	1.313
DMT6 -> DMT	0.106	1.436	0.151	0.310	3.443	0.001	TR	1.297
FC2 -> FCost	0.001	0.004	0.997	0.318	1.969	0.049	TR	1.134
FC3 -> FCost	0.923	12.560	0.000	0.991	40.546	0.000	RI	1.299
FC4 -> FCost	0.151	1.283	0.200	0.564	5.504	0.000	AI	1.292
FQ1 -> FQuality	0.254	3.757	0.000	0.726	14.086	0.000	RI	2.077
FQ2 -> FQuality	0.409	6.259	0.000	0.849	23.402	0.000	RI	2.342
FQ3 -> FQuality	0.451	9.066	0.000	0.805	19.730	0.000	RI	1.669
FQ4 -> FQuality	0.171	2.555	0.011	0.622	9.628	0.000	RI	1.480
FT1 -> FTime	0.388	4.652	0.000	0.604	7.280	0.000	RI	1.147
FT2 -> FTime	0.042	0.846	0.398	0.174	2.224	0.026	TR	1.141
FT3 -> FTime	0.204	3.193	0.001	0.431	5.089	0.000	RI	1.116
FT4 -> FTime	0.754	12.338	0.000	0.890	23.493	0.000	RI	1.123

Table 3: Response rate of copies of questionnaires distributed and retrieved

Distribution of Questionnaire	**Total**
Number distributed	600
Number Retrieved and used	544
Percentage	90.6%

Understanding the workforce's experience levels is essential for evaluating potential influences on waste management practices and project performance.

In summary, the detailed examination of respondent demographics yields valuable insights into the intricate composition of the construction industry workforce in Lagos State. These insights not only inform but also provide a foundation for tailoring construction waste management practices to the demographic profile of the workforce, aiming to enhance overall project performance. Considerations related to gender, age, educational background, professional roles, and experience levels are crucial when designing and implementing construction waste management strategies in this dynamic and diverse region.

The analysis of path coefficients in Table 5 aligns with the criteria proposed by Hair *et al.* (2019) to ascertain statistical significance, where a P-value of less than or equal to 0.05 and a T-value greater than or equal to 1.96 (at 95%) are considered significant.

Table 4: Characteristics of the Respondents Effect of Innovative Construction Waste Management Practices (ICWMPs) on Building Project Performance

Characteristics	Item	Frequency	Percentage
Gender	Male	497	91.4
	Female	47	8.6
	Total	544	100
Age	21-30 years	259	47.6
	31-40 years	205	37.7
	41-50 years	78	14.3
	Over 50 years	2	0.4
	Total	**544**	**100**
Highest Educational Qualification	OND	111	20.4
	B.Sc/HND	280	51.5
	PGD/MSc.	132	24.3
	Ph.D	2	0.4
	Others	19	3.5
	Total	**544**	**100**
Professional/owners category	Project Manager	34	6.3
	Engineer	236	43.4
	Quantity Surveyor	31	5.7
	Architect	11	2.0
	Builder	178	32.7
	Project Director/Contractor	27	5.0
	Others	27	5.0
	Total	**544**	**100**
Years of Experience	Less than 5 years	232	42.6
	5-10 years	227	41.7
	10-15 years	51	9.4
	15-20 years	22	4.0
	Over 20 years	12	2.2
	Total	**544**	**100**

Table 5: Path Coefficients for Disaggregated ICWMPs and Performance Measures

Path	Beta	STDEV	T statistics	P values	VIF	f-square	ID
DCM -> FCost	0.076	0.128	0.590	0.555	3.179	0.003	1.000
DCM -> FQuality	0.069	0.062	1.100	0.271	3.179	0.005	2.000
DCM -> FTime	0.078	0.064	1.210	0.226	3.179	0.004	3.000
DIP -> FCost	0.526	0.106	4.984	0.000	3.736	0.111	1.000
DIP -> FQuality	0.212	0.063	3.379	0.001	3.736	0.037	2.000
DIP -> FTime	0.334	0.072	4.628	0.000	3.736	0.064	3.000
DME -> FCost	0.124	0.086	1.436	0.151	2.416	0.009	1.000
DME -> FQuality	0.351	0.044	7.946	0.000	2.416	0.158	2.000
DME -> FTime	0.130	0.060	2.149	0.032	2.416	0.015	3.000
DMP -> FCost	-0.035	0.101	0.349	0.727	2.214	0.001	1.000
DMP -> FQuality	0.292	0.056	5.208	0.000	2.214	0.119	2.000
DMP -> FTime	0.170	0.062	2.755	0.006	2.214	0.028	3.000
DMT -> FCost	-0.118	0.082	1.437	0.151	2.318	0.009	1.000
DMT -> FQuality	0.014	0.045	0.320	0.749	2.318	0.000	2.000
DMT -> FTime	0.116	0.054	2.139	0.033	2.318	0.012	3.000
Endogenous Construct	**R-square**						
FCost	*0.331*						
FQuality	*0.677*						
FTime	*0.529*						

In the context of the analysis presented, a relationship between an independent variable and a dependent variable is considered to be significant at 90% when T-statistics falls within a range where it is greater than or equal to 1.65, and the associated P-value is greater than 0.05 but less than 0.1

Figure 1 and figure 2 depict the algorithm and the bootstrapping procedure to obtain both coefficients and their significance, respectively. The figures (1 and 2) were summarized into Table 5.

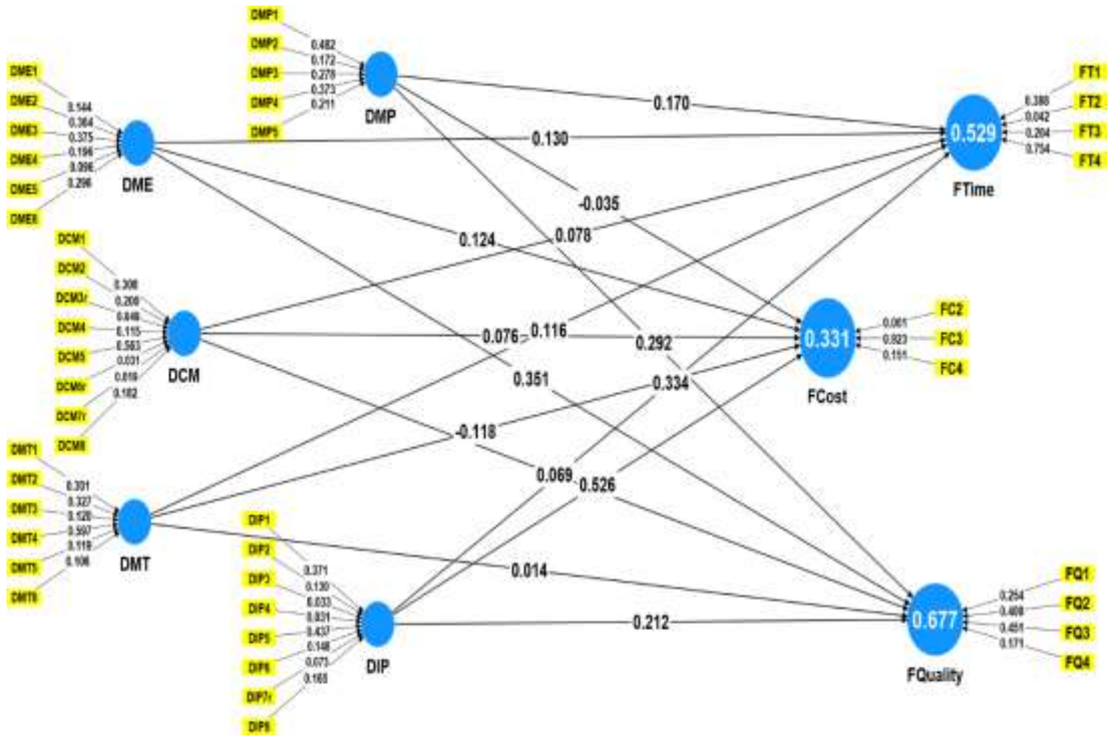

Figure 1: Algorithm for ICWMPs and Performance Indicators

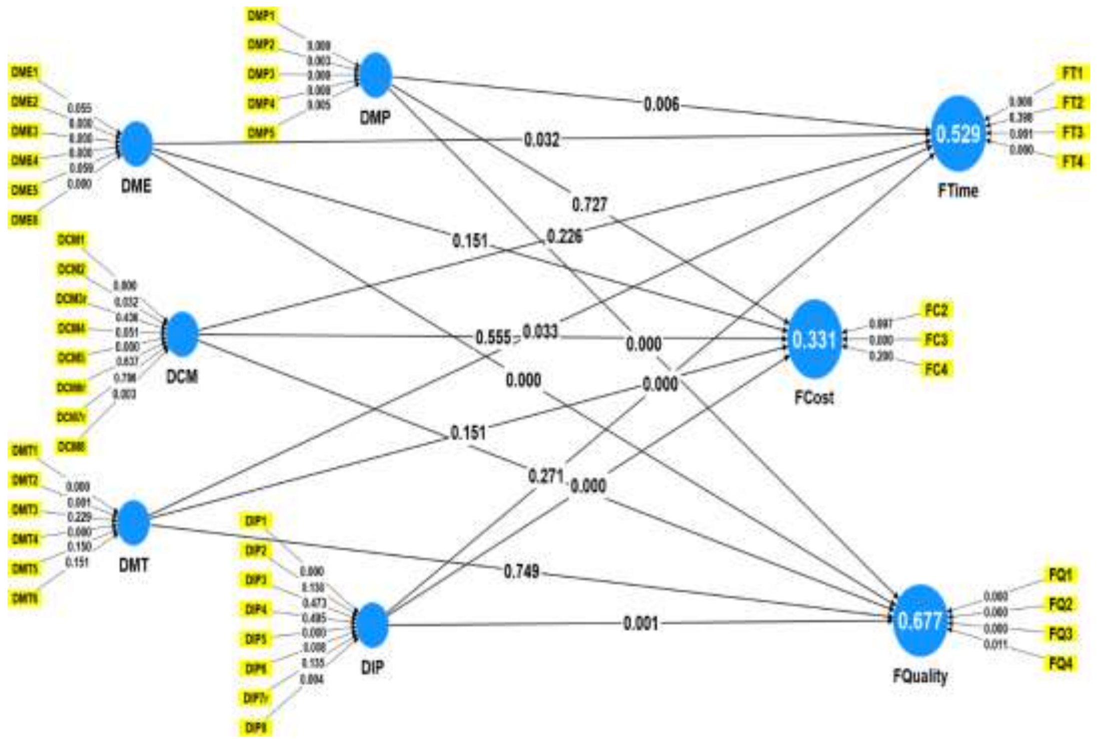

Figure 2: Bootstrapping for ICWMPs and Performance Indicators

Therein, the study reported that construction method (DCM) had no significant relationship with industry policy (DIP) that had significant relationship with all the performance measures, at 5% level of significance. The best relationship was with cost ($\beta =$ 0.526, SE = 0.106). Table 4.4 showed that innovative materials and equipment latent variable (DME) had no significant relationship with other performance sub-constructs. The greater effect of DME was found with quality performance ($\beta =$0.351, SE= 0.044). Similarly, innovative manpower approach (DMP) as a practice to control the construction waste was significant with both quality and time but not significant with cost as depicted on Table 4.4. It was also revealed from the disaggregated ICWMPs relationships with project performance measures that management practice (DMI) had a significant relationship with time performance only when its paths were examined.

Based on the endogenous constructs (cost, quality, and time), the study examined the most important exogenous factors, their significance and the coefficient of determination (R-square). For the cost performance measure, Table 5 showed that industry policy (DIP) was the most important construct to be considered ($\beta =$ 0.526, SE = 0.106). The construct's (DIP) relationship with cost rendered all others non–significant. The cost construct has an R-square value of 0.331, which according to Cohen (1992) found in Tehseen *et al.* (2019) could be ranked as being substantial. Furthermore, Time performance was higher than cost in terms of R–square value (0.529), which could be expressed as the explained variance that the exogenous construct could predict in the endogenous (that is 52.9 percent). Similar to cost, industry policy proved to be the major important variable in the mix ($\beta =$0.334, SE=0.072). The outcome of this process further strengthens the importance of professionals in the construction industry adhering to industrial policy. Finally, the highest R-square value produced by the disaggregation ICWMPs was found with the quality construct (0.677) which was similar to the disaggregated CCWMPs trend. Unlike others, innovative materials and equipment (DME) had the highest path coefficient ($\beta =$0.357, SE=0.044). This was followed by the innovative manpower approach construct (DMP) with a path coefficient of 0.292 (SE=0.056). This implies that innovative materials and equipment as well as the innovative manpower approach are required to deliver quality work in the building construction projects. Figure 3 and Table 6 show the results of aggregated ICWMPs on the performance measure (cost, quality, and time).

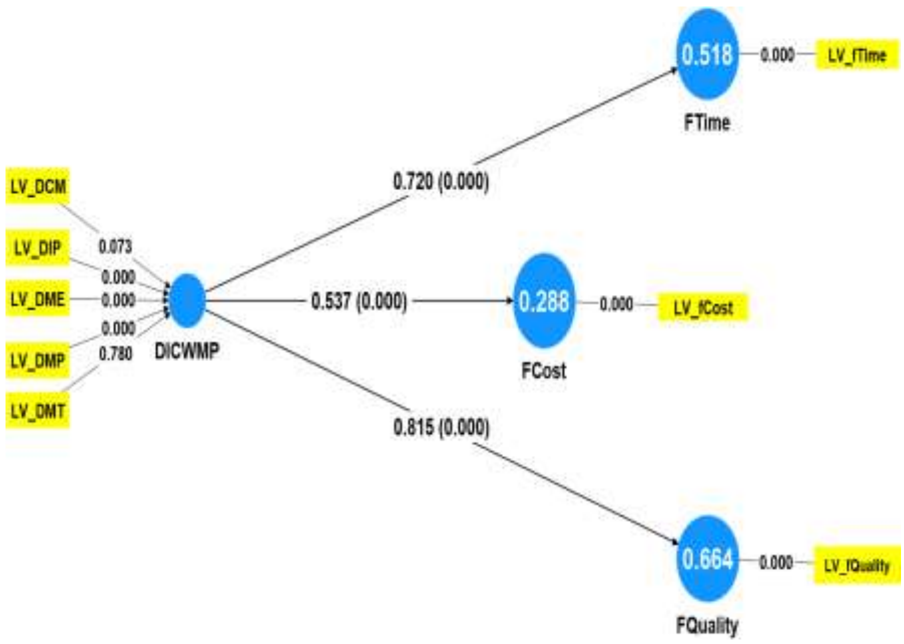

Figure 3: Aggregated ICWMPs and Performance Indicators

Table 6: Path Coefficients for Aggregated ICWMPs and Performance Measures

Path	Beta	STDEV	T statistics	P values	R-square	f-square
DICWMP -> FCost	0.537	0.050	10.765	0.000	0.288	0.405
DICWMP -> FQuality	0.815	0.018	44.640	0.000	0.664	1.978
DICWMP -> FTime	0.720	0.035	20.620	0.000	0.518	1.073

The results of the relationships were positive and significant. The effect sizes were also large and substantial. It also revealed that ICWMPs had the most impact on the quality of the project (β = 0.815, SE = 0018). This implies that a unit increase in the ICWMP was followed by a 72 percent improvement with duration of the project and lastly, about 54 percent performance on the budget of project. Furthermore, Table 6 presented the scores for the coefficient of determination (R-square) which suggested the percentage of variances the exogenous variable could predict in the endogenous variables. Here, DICWMPs was able to predict 28.8, 51.8, and 66.4 percent of cost, time, and quality constructs, respectively.

The study explores the effect of Innovative Construction Waste Management Practices (ICWMPs) on building project performance measures, uncovering notable insights. ICWMPs showcased a substantial positive impact on project performance, with a particular emphasis on quality outcomes. This finding aligns seamlessly with existing literature, as suggested by studies conducted by Tam *et al.* (2019) and Sabet Divsholi *et al.* (2019), both of who assert that innovative practices, including recycling and reuse, contribute significantly to enhanced project quality. The study's results underscore the potential of ICWMPs to elevate project standards and deliver superior outcomes in terms of the final product's quality.

DISCUSSION

The findings of the study shed light on the substantial relationships observed between Innovative Construction Waste Management Practices (ICWMPs) and various measures of building project performance. This underscores the critical role that innovative approaches play in shaping outcomes within the construction industry. These results align closely with prior research, reinforcing the notion that implementing innovative waste management strategies can yield significant benefits for construction projects. For instance, Wang *et al.* (2023) and Al-Raqeb *et al.* (2024) have also emphasized the potential advantages associated with the adoption of innovative waste management practices. Their work underscores how these strategies can contribute to improving project performance across multiple dimensions. By corroborating these findings, the current study adds further credence to the importance of embracing innovative approaches in waste management within the construction sector.

Moreover, the study's validation of the positive impact of ICWMPs on project performance echoes the sentiments expressed in the literature regarding the potential benefits of such practices. Through empirical evidence, the study reinforces the notion that innovative waste management strategies can lead to enhanced outcomes in building projects. This highlights the significance of adopting forward-thinking approaches to waste management, not only for cost savings but also for improving overall project quality and sustainability.

The findings reveal a significant positive impact of Innovative Construction Waste Management Practices (ICWMPs) on project quality outcomes, highlighting the crucial role of innovative approaches in enhancing the overall quality of construction projects. This aligns closely with previous research conducted by Tam *et al.* (2019) and Sabet Divsholi *et al.* (2019), who demonstrated the positive influence of innovative practices, such as recycling and reuse, on elevating project quality standards.

Tam *et al.* (2019) and Sabet Divsholi *et al.* (2019) have extensively explored how innovative waste management practices contribute to improved project quality. These studies emphasized the importance of incorporating recycling and reuse strategies into construction projects, showcasing how these innovative approaches can lead to superior quality outcomes. By corroborating these findings, the current study adds further weight to the body of evidence supporting the notion that

ICWMPs play a pivotal role in enhancing project quality within the construction industry.

More so, the results underscore the potential of ICWMPs to raise project standards and deliver superior outcomes, aligning closely with the sentiments expressed in existing literature. Previous research, such as that by Haider *et al.* (2022) and Poon *et al.* (2014), has also highlighted the positive effects of waste management innovations on project quality. These studies have underscored the importance of implementing innovative waste management practices from the planning stages of construction projects to ensure improved quality outcomes.

Furthermore, the study identifies several key factors that significantly influence project performance within the construction industry, shedding light on critical aspects that can shape the outcomes of building projects. Industry Policy (DIP) emerges as a pivotal factor with a substantial relationship, particularly concerning cost performance measures. This finding underscores the significant role of regulatory frameworks and policies in driving effective waste management practices within the construction sector. As highlighted by Osmani *et al.* (2008), the presence of robust industry policies is essential for fostering a conducive environment for implementing waste management strategies. These policies serve as guidelines that govern waste handling practices, ensuring compliance with environmental standards and promoting sustainability within construction projects.

In addition, the study emphasizes the importance of Innovative Materials and Equipment Management (DME) and Innovative Manpower Approach (DMP) in optimizing project performance. Both aspects play crucial roles in delivering quality work in construction projects, highlighting the significance of adopting innovative approaches not only in material handling but also in workforce management. This aligns with prior research advocating for the application of lean principles and efficient resource utilization in construction projects.

The findings underscore the importance of incorporating innovative practices in material and equipment management, as well as workforce allocation, to enhance overall project performance. By leveraging innovative materials and equipment effectively and optimizing manpower allocation, construction projects can achieve higher levels of efficiency and productivity. These insights reinforce the need for construction stakeholders to embrace innovative strategies and technologies to drive positive outcomes in project execution.

CONCLUSION

The study investigated the effect of Innovative Construction Waste Management Practices (ICWMPs) on building project performance in Lagos State, Nigeria, uncovering significant relationships between the two. Through a methodology employing Partial Least Squares in Structural Equation Modeling (PLS-SEM) using SMART PLS-4, the research assessed various variables to determine their impact on project performance. The variables measured encompassed both exogenous constructs, such as innovative construction waste management practices, and endogenous constructs, namely cost, time, and quality performance. Industry policy (DIP) emerged as a standout factor with a substantial relationship, particularly in relation to cost performance measures. This finding underscores the crucial role of regulatory frameworks and policies in driving effective waste management practices within the construction sector, aligning with prior research in the field. Furthermore, the study highlighted the significance of innovative materials and equipment management (DME) and innovative manpower approach (DMP) in delivering quality work in construction projects. Both factors demonstrated their importance in optimizing project performance, emphasizing the need for stakeholders to adopt innovative strategies not only in material handling but also in workforce management. Disaggregating ICWMPs further emphasized the importance of adhering to industry policy, as it emerged as a major influential factor in the mix. The analysis revealed that innovative materials and equipment, coupled with the innovative manpower approach, significantly contributed to achieving quality outcomes in building construction projects. The structural model analysis underscored the importance of these factors in influencing cost, quality, and time performance measures. Aggregating ICWMPs also highlighted their positive impact on project performance, with the most substantial effect observed on project quality, followed by duration and budget. The coefficient of determination (R-square) scores provided insights into the predictive power of ICWMPs, indicating their ability to forecast a significant portion of cost, time, and quality constructs. Specifically, ICWMPs were able to predict 28.8%, 51.8%, and 66.4% of cost, time, and quality constructs, respectively, indicating their substantial influence on project outcomes. In recommending practical implications, the study suggests that construction industry stakeholders in Lagos State should prioritize adherence to industry policy, efficient innovative materials and equipment management, and strategic innovative manpower approach in order to optimize project performance. These findings contribute to the body of knowledge by identifying key factors influencing project performance and validating the substantial impact of ICWMPs. Future studies may further investigate the implementation challenges and success factors of ICWMPs in different cultural and regional contexts, providing a comprehensive understanding of their applicability and effectiveness in diverse settings. Such research endeavours would contribute to enhancing waste management practices and optimizing project performance in the construction industry.

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Appendix

Constructs and Indicators for Innovative Construction Waste Management Practices in Lagos State

KEY: 5=Strongly Agree, 4=Agree, 3=Moderately Disagree, 2 = Disagree, 1 = Strongly Disagree

Innovative CWM Practices						
	INNOVATIVE MANPOWER APPROACH	**5**	**4**	**3**	**2**	**1**
1.	Commitment of contractor's representative at a site					
2.	Appointment of labourers solely for wastes disposal					
3.	Organization breakdown structure involved in waste management					
4.	Education of the contractor's staff (engineers)					
5.	Education of the sub-contractors' staff (labourers)					
	INNOVATIVE MATERIALS AND EQUIPMENT	**5**	**4**	**3**	**2**	**1**
1.	Minimizing rework on a construction phase					
2.	Design and construction using standardized materials					
3.	Prefabrication of materials					
4.	Use of recycled materials					
5.	Preventing easily fragile materials from being used					
6.	Minimizing loss of materials during carrying and storing					
	CONSTRUCTION METHOD	**5**	**4**	**3**	**2**	**1**
1.	Designate a place for storing wastes in an early stage of construction					
2.	Storing wastes at an easily accessible area					
3.	Installing equipment for recycling in a site					
4.	Installing an information board to notice categories of separating wastes					
5.	Information board to deal with the rest of the wastes after recycling					
6.	Prohibiting the use of pipes for dumping down mixed wastes					
7.	Notice on waste type and the responsible staff to waste bins					
8.	Notice on recyclable materials to labourers					
	MANAGEMENT PRACTICE	**5**	**4**	**3**	**2**	**1**
1.	Rules on dealing with wastes by waste generators					
2.	Contractual clauses for a subcontractor in dealing with wastes					
3.	Establishing waste management plan in an early stage of construction					
4.	Checklist on executing detailed waste management plan					
5.	Confirming capability of a firm that treats wastes					
6.	Managing data for wastes by a head office					
	INDUSTRY POLICY	**5**	**4**	**3**	**2**	**1**
1.	Obligatory cost estimation for quantity waste treatment in a bill					
2.	Enhancing punishment for illegal treatment of waste					
3.	Supervising waste management by a residential officer					
4.	Tax free for waste treatment equipment					
5.	Simplifying legal procedures to install waste treatment equipment					
6.	Establishing criteria for quality and safety of recycled materials					
7.	Constructing marketing structure for recycled materials					
8.	Database management system for construction wastes					

Constructs and Indicators for Building Projects Performance Measures

KEY: 5=Strongly Agree, 4=Agree, 3=Moderately Disagree, 2 = Disagree, 1 = Strongly Disagree

	TIME	**5**	**4**	**3**	**2**	**1**
1.	Building projects starts at the planned time					
2.	Waste management plan affects the project start date					
3.	Waste management implementation causes variation in project schedule					
4.	Building are completed within the planned project duration					
	COST	**5**	**4**	**3**	**2**	**1**
1.	Estimate considers waste minimization plan					
2.	Estimate enables waste minimization					
3.	There is proper budget planning					
4.	No excessive project cost as a result of waste management					
	QUALITY	**5**	**4**	**3**	**2**	**1**
1.	Buildings serve the purpose for which they are constructed					
2.	Building projects are delivered in compliance to specification					
3.	Building projects deliver expected aesthetic merits					
4.	Building projects are usually durable					