

Construction Waste Management Practices for Sustainable Development in Ibadan Oyo State Nigeria

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Research Article

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Abstract

Rapid urbanisation has increased construction waste in Nigerian cities; however, the drivers, constraints and practices shaping its management remain poorly documented at the city level. This study investigated construction waste management practices, the constraints hindering them, and sustainability solutions in Ibadan, Oyo State. A descriptive survey was administered to 60 construction professionals purposively and snowball-sampled at active building sites, and the data were analysed descriptively alongside chi-square testing, multiple regression, factor analysis, and binary logistic regression. Recycling and formal waste collection were the most institutionalised practices (mean = 3.05 each), while on-site material storage lagged significantly (mean = 2.67), indicating uneven rather than systematic implementation. Limited recycling infrastructure was the most severe constraint (mean = 3.12). Years of experience and professional role jointly explained 41.2% of the variance in sustainable practice adoption ($R^2 = 0.412$, $p < .001$), and recycling facility availability was the strongest predictor of waste management plan implementation ($\text{Exp}(B) = 2.010$, $p = .007$). Factor analysis identified three underlying dimensions as preventive, recovery, and systematic practices accounting for 58.9% of the variance, suggesting implementation remains fragmented rather than integrated. Given the small, non-probability sample, these associations are indicative rather than generalisable. Overall, construction waste management in Ibadan is reactive rather than strategic, and the study recommends mandatory construction waste management plans, targeted infrastructure investment, and structured professional training to address the identified gaps.

1. Introduction

The construction sector is a key sector in economic growth and infrastructure development globally, providing housing, transportation, commercial, and public infrastructure that supports social and economic development [1]. It is also, however, one of the largest producers of solid waste in the world, with well-documented environmental and economic consequences across the construction lifecycle [2]. When poorly managed, construction waste, which includes concrete, timber, metals, plastics, glass, and packaging materials generated by the construction, renovation, and demolition process, leads to environmental degradation, public health hazards, and unsustainable depletion of natural resources [3]. With increasing urbanisation and construction activities, waste generation in cities has rapidly increased, and therefore, construction waste management has become one of the main issues in sustainable built environment development [4]. The concept is based on three pillars, namely waste avoidance at source, stimulation of re-usage and recycling, and safe disposal of dangerous residues [5], all of which contribute to the conservation of natural resources, reduction of emissions, and efficiency in the construction sector [6].

The implementation of these principles is, however, significantly patchy and is relatively poor in developing countries where regulatory frameworks, waste infrastructure, and technical skills are relatively underdeveloped [7, 8]. Often, environmental concerns are secondary to cost, and schedule constraints and wastes are disposed of improperly instead of being reduced, reused, or recycled [9].

Comparable patterns have been documented outside Nigeria: in Northern Ethiopia, illegal dumping has been found to be the dominant disposal method for construction and demolition waste, driven largely by inadequate infrastructure, weak regulation and low stakeholder awareness [10, 11]. Nigeria is a case in point of these dynamics. The population growth and rapid urbanisation have led to a growth in construction activity in the major cities, resulting in a large amount of waste generated by the transport, residential, and commercial development [12]. Despite this, construction waste management in the country is still dominated by the collection and disposal of waste, while reduction and recycling, as well as material recovery, are comparatively less emphasised [13], which is due to poor implementation of regulations and the lack of recycling facilities [14]. The tension is reflected in Oyo State and its capital, Ibadan. The population growth and the growing demand for housing, roads, and other infrastructure have led to an increase in construction activity in all categories of residential, commercial, and infrastructural sectors, which have caused the production of concrete waste, timber waste, metal waste, plastic waste, and packaging waste [8].

There is no systematic process to waste disposal at many of the sites, and the resulting improper disposal is increasingly becoming visible in the environment of Ibadan, causing drainage blockages, flooding, emissions from open burning of the waste, and contamination of the soil and water resources in the city, which compromise the health of the population and the sustainable urban development Ibadan's growth trajectory would otherwise warrant [15, 16, 17]. However, available evidence reveals that the management of construction waste at the construction site in Ibadan does not adequately reflect the environmental and sustainability goals, even at a visible cost, which is limited [14]. The lack of adequate disposal sites, technical knowledge among workers and contractors, non-enforcement of environmental regulations, and the cost and time considerations as top priority over sustainability are common challenges in the implementation of effective waste management [3]. But these barriers have not been studied empirically in Ibadan's construction practice, and their relative importance and interaction remain unproven [13].

In addition, although the practice of waste sorting, reuse recycling, material recovery and suitable on-site storage is highly encouraged, there is limited evidence of their level of implementation on construction sites in Ibadan and the resulting reduction in environmental damage [15]. Their role in achieving sustainable development goals, including pollution control and enhancing liveability in urban areas, has not been adequately assessed locally. This study is in response that gap. To provide empirical-based information regarding the current management of construction waste materials on Ibadan construction sites, problems that limit good construction waste management practices, and sustainable approaches to better construction waste management in fast-growing Nigerian cities for policy design and industry practices and for research. In particular, the study examines the construction waste management practice and how sustainable development can be improved through appropriate practice and strategies in the city of Ibadan in Oyo State Nigeria, with the following three objectives:

- 1. to examine current construction waste management practices in Ibadan;*
- 2. to identify the challenges affecting effective construction waste management; and*

3. to evaluate the sustainable construction waste management strategies adopted on selected construction sites.

2. Literature Review

2.1 Conceptual Review

Construction waste is the term used for materials that are not used or wanted in the construction, renovation, repair, or demolition of a building or infrastructure project, including concrete, bricks, timber, metals, plastic, glass, packaging, and soil [17]. It comes with material damage, the over-ordering of materials, mishandling and non-utilisation during construction [3], and from the deliberate removal and discard of materials during demolition [6]. It is one of the largest sources of solid waste in the world, and its volume grows with urbanization [13], and if not managed well, it will contribute to pollution, pressure on landfill sites, depletion of resources, and health problems; for instance, when waste is dumped on land or drainage channel it will cause flooding and contamination of the water [18]. The classification of construction waste into inert waste (concrete, bricks, stone), recyclable waste (metals, plastics, wood) and hazardous waste (asbestos, chemical containers, treated materials) [19] is important as they all require different handling and disposal paths. Therefore, deliberate design that minimises material use, reuses materials, recycles valuable materials, and ensures responsible disposal of any waste remaining [20] is essential to good management.

2.2 Construction Waste Management Practices

Construction waste management practices are the methods employed in managing, controlling and reducing the construction waste generated during the construction process [7]. Effective execution can help to lessen landfill reliance and direct construction effort towards sustainability [21, 19], starting with the coordination of all parties involved in the construction project, particularly the contractors, site managers, engineers and the regulators [8, 22]. Reducing waste at source by properly planning projects and estimating materials prevents over-ordering and the resulting waste [23]. Materials are also less likely to be damaged as a result of the correct storage and handling, which creates unnecessary waste [24]. The benefits of on-site sorting and segregation, separating concrete, metals, wood, plastics and packaging at the point of generation and diverting recyclable material away from the general waste stream, have been illustrated by an improvement in recycling efficiency [22, 25].

Reuse extends the life of the components that come from demolition and other components that are left over from construction, thus conserving resources and reducing the need for new raw materials [13, 8], a preference borne out elsewhere in the literature, where reuse has been identified as the most favoured construction waste management method among practitioners [26]. Recycling converts waste materials, metals, plastics and especially concrete materials into useful raw materials, reduces environmental pollution, and reduces landfill pressure [5, 14]. Ensuring that waste that can't be reused or recycled is

collected and disposed of correctly, rather than illegally, ensures it reaches approved facilities, and hazardous waste needs to be handled specially to prevent any impact on the environment [27, 24]. These individual practices are formalised in waste management plans that outline procedures for waste reduction, segregation, storage, recycling and disposal and hold project stakeholders accountable [25].

2.3 Challenges Affecting Construction Waste Management

Although the issue is gaining momentum, numerous challenges are still being encountered by both industry and government regarding the management of construction waste, which results in sub-optimal outcomes and loss of materials [9, 6]. One of the most significant of these challenges is inadequate waste management infrastructure. In many developing countries, recycling systems are still underdeveloped, and companies simply dump the waste on open land, at roadside dump sites or in drainage systems, resulting in pollution and flooding issues [20, 9, 23, 14], a pattern that reflects the fact that illegal disposal often remains the lowest-cost option available to contractors operating in emerging economies [28]. The lack of knowledge and technical skill among workers and contractors also aggravates the issue, as many lack training in waste segregation and recycling procedures, and safe handling of hazardous waste, resulting in waste being mixed and disposed of without considering its economic value, and leading to the loss of valuable materials [3; 34, 25, 27].

Weak enforcement of environmental law is a further constraint. Although there is a regulatory framework in place in most jurisdictions, the monitoring of compliance in most cases is weak, and agencies often lack staff and resources to ensure compliance, thereby allowing non-compliant firms to evade any penalty [29, 13, 15, 5]. Limited financial resources discourage investments in sorting, collection and transport of waste, especially for small and medium-sized contractors who consider these to be unnecessary overheads and focus on cost-cutting and keeping to schedule [7, 21, 19]. Not only do these structural constraints exist, but there is also inefficient material planning. Poor planning causes over-ordering due to inaccurate estimation, or inadequate storage results in the loss of material that should have been used, which is causing construction waste both ways [18, 30, 31, 4].

2.4 Sustainable Construction Waste Management Strategies

The adoption of sustainable construction waste management strategies is linked with reducing pollution, resource consumption and enhancing the process efficiency, while also leading to less waste generation and better handling of the residual material [25], although recent work emphasises that the uptake of such strategies depends as much on organisational and behavioural drivers as on the technical availability of the practices themselves [32]. Waste minimisation during the design stage is achieved by using standardised building elements and accurate material specification, thus avoiding waste during the construction process [19, 31, 18]. Concrete, metal, wood and plastic recycling reduces

the waste flowing to landfills and re-enters the manufacturing process of these materials in subsequent projects [7, 9, 23], and life-cycle evidence confirms that circular strategies such as enhanced recycling and material recovery outperform conventional waste handling across a wide range of environmental impact categories [33].

The reuse of demolition and surplus materials in different projects will help to reduce the amount of waste and the need for new materials [34, 4, 24, 15]. Technological choice (rather than site management alone) can impact waste outcomes through on-site waste reduction and enhanced productivity due to the production of prefabricated or modularised components, which are assembled on site [21, 9, 19]. Emerging digital tools, particularly Building Information Modelling, have similarly been proposed as a means of integrating waste considerations earlier into project planning and tendering processes, especially where data on waste generation and material flow are otherwise scarce [35, 36]. Training and awareness activities for workers and contractors strengthen adherence to environmental standards and support the broader uptake of sustainable practice [3, 29, 1].

2.5 Theoretical Framework

This study tries to explain the waste reduction, resource efficiency and sustainable material management in the construction industry based on Waste Management Hierarchy Theory and Circular Economy Theory.

The Waste Management Hierarchy has been used to rank the environmental preferences for interventions [3] and was officially introduced in the European Union Waste Directive of 2008 [20]. Prevention is the top, because it is possible to avoid waste before it is even created, by improving production processes, and using materials more efficiently [4, 18, 9]. The next step is reuse, where the material is reused without a lot of reprocessing [34, 23], followed by recycling, which is the process of converting waste into new raw material and reducing the amount of waste disposed of [7, 5]. Recovery and disposal lie at the bottom levels [9, 20]. The study finds that the practices are differently institutionalised, and the hierarchy behind this is that prevention and reuse are better than recycling and recycling is better than disposal, as proposed by [6] and [19] in Ibadan.

Circular Economy Theory is a concept developed by Pearce and Turner [37] and championed by various organisations, including the Ellen MacArthur Foundation [9], which presents the traditional linear model as extraction, production, consumption, and disposal of goods while a circular one involves materials being kept in circulation through reuse, recycling, repair, and remanufacture [7, 6]. In the construction industry, that means using construction materials efficiently, maximising the value of the demolished material, reusing building components, and limiting its extraction and waste, extending material life in a modular way [23, 24, 21].

2.6 Empirical Review

However, there is limited empirical evidence of construction waste management in Nigeria. Ogunseye et al. [16] explored the perceptions of the stakeholders involved in the policy-making process, waste management and industry stakeholders in terms of policy priorities and the underdeveloped waste management process to build waste, using qualitative analysis of secondary sources. It is based on secondary (qualitative) material and does not provide much information on how individual professionals actually behave on active sites, which the present study aims to directly answer.

A study by Yakubu et al. [17] of Triacta Nigeria Ltd in Bauchi State, using survey questionnaires answered by 84 employees, showed that demolition waste, excavated soils, and unutilized building materials contributed most to the waste stream, and that waste reduction, reuse, and recycling enhanced the efficiency of materials and cost outcomes of the projects. However, they are limited in terms of generalisability due to their single-firm case design and do not reflect the variation across professional roles and project types that a multi-site sample would be able to. Both of the two studies cited are limited to one organisation, and there is a visible lack of studies which have looked at multi-site practice at the city scale and analysed it quantitatively; this study does so.

2.7 Research Gap

A significant volume of literature has emerged in the field of construction waste management, covering waste generation, waste management systems and the need for sustainable waste management strategies at both national and international levels [9, 6, 23], yet recent bibliometric and mapping reviews of this literature indicate that it remains fragmented and siloed around generation, disposal and impact themes rather than forming an integrated body of knowledge [38, 39]. There is a lower coverage of some of the developing country urban settings, and existing studies in Nigeria have largely focused on general municipal waste systems or issues identified in isolated locations, excluding Ibadan specifically [20].

While in principle, the challenges of poor infrastructure, weak enforcement of regulations and limited awareness among stakeholders are well documented, the impact of these issues on actual practice on site is rarely measured, consistent with a broader observation that the quality and availability of construction, demolition and excavation waste data remain a persistent constraint on evidence-based policy-making even in jurisdictions with established reporting systems [40]. In the same vein, there are fewer empirical evaluations of the performance of each sustainable strategy (sorting, recycling, reuse, and formal planning) in Ibadan than conceptual ones. Another constraint is the portrayal of practices, challenges, and strategies as three individual entities and not as a continuum [5]. This study moves away from this fragmentation by examining all three practices in an empirical framework, and by using multivariate statistical methods such as factor analysis, regression, and logistic regression, the interdependence among these practices and the predictors can be tested and not assumed [14; 21].

3. Methodology

The research methodology flow chart is given in Fig. 1. A descriptive survey design has been chosen. The design was appropriate for the study as it allowed for systematic data collection on the current conditions, practices and opinions of respondents who had first-hand knowledge of the study problem: construction professionals actively involved in project delivery [1]. The design is, however, cross-sectional and correlational, not experimental and hence the statistical associations reported in the present study, including regression and logistic regression coefficients, are meant to represent patterns of co-occurrence measured at one time and do not imply any causal directions.

This study was carried out in Ibadan, Oyo State, Nigeria. Ibadan is the capital of Oyo State, and is one of the largest cities in Nigeria, an important economic, commercial and educational hub in the south-west of Nigeria. The city has seen a rapid urban growth in recent years as a result of population growth, economic development activity and the demand for housing and infrastructure in the city [8]. Construction growth has produced a significant amount of construction waste, such as concrete debris, wood, metals, plastics and packaging waste. However, construction waste management in the city continues to have challenges arising from the poor implementation of environmental policies, inadequate waste management systems, and the absence of effective recycling programmes [14], which makes Ibadan an appropriate and illustrative place to study construction waste management practice and possible solutions to improve it.

The study population consisted of construction professionals and site workers in construction projects of Ibadan, such as Architects, Builders, Contractors, Quantity Surveyors, and site supervisors on active construction sites in the study area [17]. The professionals were chosen because they have first-hand knowledge of waste produced, managed and issues faced at the point of construction, as they are directly involved in the planning, implementation and administration of the projects.

The non-probability sampling technique was employed because there is no official register of construction professionals who are active in Ibadan building sites [13]. Sixty respondents, including architects, builders, engineers, contractors, quantity surveyors, and site supervisors on active construction sites throughout the city, were recruited. The respondents were selected using purposive and snowball sampling techniques. Purposive sampling was used to recruit respondents who had first-hand knowledge of construction waste management, and snowball sampling was used to recruit respondents from other sites from the respondents who completed questionnaires.

There are obvious trade-offs involved in this approach that must be borne in mind when interpreting the findings. The two types of sampling used, purposive and snowball sampling, do not provide probability-based estimates, and the sample cannot be considered as being representative of the construction workforce in Ibadan, while referral-based recruitment could lead to respondents being concentrated in the same networks. It is also a relatively small sample size when compared to the number of predictors included in the multivariate models reported in Section 4, 4 predictors in the multiple regression and 5 in the logistic regression, despite being still in the realm of possibility. These conditions will be discussed again in Section 4.6.

A structured questionnaire was used to gather primary data on the practices, challenges, and sustainable solutions related to construction waste management (CWM) from the respondents on the active construction sites of Ibadan, Nigeria. Primary data was collected using a structured questionnaire from the respondents in the active construction sites of Ibadan, Nigeria, on the practices, challenges, and sustainable solutions concerning construction waste management (CWM). Questionnaires were also sent electronically by Google Forms to maximise the response rate, and in order to maximise the reach of the questionnaires to the respondents identified through snowball referral, and after initial site contact, survey links were sent via mobile messaging [20]. Physical and electronic distribution increased coverage but may also have created a mode effect, as the paper-based on-site responses could be different from the independent, internet-based responses, which were not formally tested.

A structured questionnaire was used as a research instrument, designed to collect information about the practices of construction professionals, the challenges that hinder good waste management and the sustainable measures for good waste management [3]. The questionnaire was a mixture of closed-ended and Likert scale questions with a four-point scale that ranged from Strongly Disagree (1) to Strongly Agree (4) regarding the key variables in the study.

Validity is the extent to which a research instrument measures what it is designed to measure. In accordance with expert or face validity assessment, questionnaire items were developed directly for this study, and items were reviewed by the research supervisor and other competent persons in construction management for conciseness, relevance and appropriateness of the instrument. Their suggestions were reflected in the final version to be given to the respondents.

A quantitative validity result was not included in this process, however. The judgements of the expert panel did not provide any content validity index or ratio, nor was there any exploratory examination of item construct alignment done before the data collection, aside from the factor structure reported in Section 4.5.3. Expert review is a way of determining the appropriateness of the items to competent judges, not a way of determining the degree of agreement of the reviewers or of determining the extent to which the items together represent the constructs that the study purports to measure. This is a substantive gap which should be bridged, at least by a reported content validity index, before the use of the instrument in further research.

To ensure reliability (consistency and stability in measuring the constructs of interest), a pilot test was conducted with construction professionals who were not part of the main sample. The instrument was then pre-tested with the pilot respondents to assess internal consistency of the responses and to improve the wording of the instrument to ensure clarity.

Like validity, quantification was not reported as a result of this process. In the main dataset, no Cronbach's alpha or other internal consistency statistic was calculated for the pilot data, or for the three subscales (practices, challenges, and strategies) that were measured on the Likert-scale data. This omission is consequential as it means that readers are not provided with any opportunity of self-assessing the seven items in each subscale as a unit, and the factor analysis in Section 4.5.3, though

informative of dimensionality, is a poor substitute for a reliability coefficient. The methodology, as far as this, is procedurally described but not empirically demonstrated. A Cronbach's alpha level should be performed with the current data set for each subscale and reported; and a Cronbach's Alpha level of at least 0.70 should be considered as the minimum acceptable level in conformance with the conventional practice in survey-based construction management research.

Descriptive and inferential statistics were used for the analysis of the data. The responses on the Likert scale were coded and summarised using frequency distribution, percentages, means and standard deviations [17], and where the mid-point of the scale provided a mean of 2.50, it was used as the threshold for agreement. The inferential analysis included chi-square tests of association, multiple regression, which identified predictors of sustainable practice adoption, principal component factor analysis, which identified dimensions of practice, and binary logistic regression to identify practice waste management plan implementation predictors [9]. All analyses were carried out using SPSS version 26.0 and were considered to be statistically significant at $p < .05$.

Two methodological observations need to be made. Several of the predictors in the regression and logistic regression models are nominal categorical variables with more than two categories, and they are coded according to the practice of dummy or indicator coding, however, the meaning of the reference category adopted for each is not reported, information that should be reported explicitly in any resubmission because it is necessary for the correct interpretation of the coefficients reported for each model. Second, a sample of 60 is sufficient, but not generous, for the factor analysis in Section 4.5.3; the item-to-case ratio of $\sim 1:8.6$ is close to the minimum suggested in the literature; the Kaiser Meyer Olkin value of 0.712 is indicative of sampling adequacy, but cannot be taken as conclusive until replicated in a larger sample.

4. Results and Discussion

4.1 Demographic Characteristics of Respondents

The demographic characteristics of the 60 respondents are presented in Table 1. The top professional group of site supervisors (18.3%, $n = 11$) was followed by architects (16.7%, $n = 10$), quantity surveyors (15.0%, $n = 9$), and engineers, builders, and contractors (13.3%, $n = 8$ each), and other professionals (10.0%, $n = 6$). Most respondents had 11 to 15 years of experience (43.3%, $n = 26$), followed by 5 to 10 years (31.7%, $n = 19$), 16 to 20 years (18.3%, $n = 11$), and fewer than 5 years (6.7%, $n = 4$). The most frequently occurring project types were residential buildings (41.7%, $n = 25$), commercial buildings (25.0%, $n = 15$), infrastructure projects (23.3%, $n = 14$) and mixed-use developments (10.0%, $n = 6$). The most prevalent role was that of a project manager (26.7%, $n = 16$), followed by site supervisor (21.7%, $n = 13$), engineer or architect (20.0%, $n = 12$), construction manager (20.0%, $n = 12$) and other roles (11.7%, $n = 7$).

Table 1
Demographic Characteristics of Respondents

Variable	Category	Frequency (n)	Percentage (%)
Profession	Site Supervisor	11	18.3
	Architect	10	16.7
	Quantity Surveyor	9	15.0
	Engineer	8	13.3
	Builder	8	13.3
	Contractor	8	13.3
	Others	6	10.0
	Total	60	100.0
Years of Experience	Less than 5 years	4	6.7
	5–10 years	19	31.7
	11–15 years	26	43.3
	16–20 years	11	18.3
	Total	60	100.0
Project Type	Residential buildings	25	41.7
	Commercial buildings	15	25.0
	Infrastructure projects	14	23.3
	Mixed projects	6	10.0
	Total	60	100.0
Position	Project Manager	16	26.7
	Site Supervisor	13	21.7
	Engineer/Architect	12	20.0
	Construction Manager	12	20.0
	Others	7	11.7
	Total	60	100.0

The sample is weighted toward mid-career professionals, with more than 60% reporting 11 or more years of experience. This skew matters later in this section, because years of experience is a significant

predictor in both the regression and logistic regression models, a sample concentrated among experienced professionals restricts the range of that predictor and may understate its true effect.

4.2 Current Construction Waste Management Practices

Table 2 reports the mean and standard deviation scores for current waste management practices. All seven items exceeded the 2.50 agreement threshold, with scores ranging from 2.67 to 3.05. Recycling and proper collection and transportation to approved disposal sites received the highest ratings (mean = 3.05 each), followed by material estimation and material reuse (mean = 2.92 each). On-site sorting and segregation (mean = 2.90, SD = 0.86) and waste management plan implementation (mean = 2.83, SD = 0.78) trailed slightly, while proper on-site storage recorded the lowest rating (mean = 2.67, SD = 0.91) and, together with segregation, the widest dispersion of responses, indicating that these two practices are applied least consistently across sites.

Table 2

Mean and Standard Deviation Responses on Current Construction Waste Management Practices

Statement	Mean	SD	Decision
1. Proper material estimation is carried out to reduce construction waste	2.92	0.65	Agreed
2. Construction materials are properly stored on site to prevent damage and waste	2.67	0.91	Agreed
3. Construction waste materials are sorted or segregated on site	2.90	0.86	Agreed
4. Construction companies reuse materials such as timber, bricks or metals	2.92	0.77	Agreed
5. Construction waste materials are recycled where possible	3.05	0.72	Agreed
6. Construction waste is properly collected and transported to approved disposal sites	3.05	0.79	Agreed
7. Waste management plans are implemented during construction projects	2.83	0.78	Agreed
<i>Decision rule: Mean $\geq$ 2.50 = Agreed; Mean $<$ 2.50 = Disagreed</i>			

These results indicate that construction waste management practices are evident across Ibadan's construction sites, but the pattern is one of selective rather than comprehensive implementation. Recycling and formal collection are the most institutionalised activities, echoing Yakubu et al. [17], whose Bauchi State case study similarly found waste minimisation, reuse, and recycling to be the practices construction firms adopt most readily, largely because they deliver visible cost and efficiency benefits. This finding is also consistent with evidence from residential building projects elsewhere, where recycling has similarly been identified as the most readily adopted practice once waste and recycling issues are formally prioritised through structured importance-ranking exercises. The comparable

strength of material estimation and reuse points to an emerging resource-conscious culture within the sector, one plausibly driven more by cost discipline than by environmental commitment as such.

The weaker and more variable performance of on-site storage and formal waste management planning is the more consequential finding. Formoso et al. [18] identify substandard storage and handling as a primary cause of construction waste, and the low mean and wide dispersion recorded here ($SD = 0.91$) suggest that storage practice varies considerably by site, plausibly reflecting differences in contractor capacity or supervision rather than any uniform standard. That waste management plans remain the least institutionalised formal instrument is telling: individual waste-related activities occur, but the coordinating framework meant to organise them across a project's life cycle largely does not, consistent with the fragmented implementation Ogunseye et al. [16] describe more broadly for Nigerian construction and demolition waste governance, and echoing a broader industry pattern in which formal waste management planning is rarely integrated into mainstream project management processes such as cost and schedule control, a shortcoming that has recently prompted efforts to embed waste performance monitoring directly into project management frameworks [41].

4.3 Challenges Affecting Construction Waste Management

Table 3 reports responses to challenges to effective waste management. All seven items again exceeded the agreement threshold, ranging from 2.77 to 3.12. Limited recycling facilities were rated the most significant constraint (mean = 3.12, $SD = 0.72$), followed by poor material planning and estimation (mean = 3.00) and inadequate training (mean = 2.98, $SD = 0.57$), the latter also carrying the lowest standard deviation of any item in the study, indicating close to universal agreement. Inadequate infrastructure (mean = 2.97), weak regulatory enforcement (mean = 2.88), limited awareness (mean = 2.83), and financial constraints (mean = 2.77) were also identified as material barriers.

Table 3

Mean and Standard Deviation Responses on Challenges Affecting Construction Waste Management

Statement	Mean	SD	Decision
1. Lack of proper waste management infrastructure affects construction waste management	2.97	0.84	Agreed
2. Limited recycling facilities hinder effective construction waste management	3.12	0.72	Agreed
3. Lack of awareness among construction workers affects proper waste handling	2.83	0.74	Agreed
4. Inadequate training on waste management practices affects construction projects	2.98	0.57	Agreed
5. Weak enforcement of environmental regulations affects construction waste management	2.88	0.74	Agreed
6. Financial constraints limit the adoption of sustainable waste management practices	2.77	0.72	Agreed
7. Poor material planning and estimation contribute to construction waste generation	3.00	0.71	Agreed
<i>Decision rule: Mean $\geq$ 2.50 = Agreed; Mean $<$ 2.50 = Disagreed</i>			

The challenges identified here converge on a familiar developing country profile, infrastructural, educational, regulatory, and financial constraints operating simultaneously rather than singly. Limited recycling infrastructure was rated the most severe constraint, corroborating Ogunseye et al.'s [16] observation that construction and demolition waste receive markedly less infrastructural support than municipal solid waste in Nigeria, and [20] identification of recycling infrastructure as a binding constraint across developing regions generally. The near-universal agreement on inadequate training, with its standard deviation the lowest of any item in the study, is a rare point of consensus and corroborates [3] finding of systemic knowledge gaps among construction workers regarding segregation, recycling, and hazardous waste handling.

Weak regulatory enforcement and financial constraints were rated significant but comparatively less severe than infrastructure and training. This ordering suggests that, in respondents' own assessment, the binding constraint on better practice is capacity, having the facilities and the knowledge to act, rather than incentive, being penalised for not acting or unable to afford acting. If accurate, this reorders the policy priority implied by much of the enforcement-focused literature [15]: infrastructure and training investment may yield faster returns than regulatory tightening alone, though the two are best pursued together.

4.4 Sustainable Waste Management Strategies

Table 4 reports responses to sustainable waste management strategies. All seven items exceeded the agreement threshold, ranging from 2.65 to 3.03. Recycling was rated the most effective strategy (mean

= 3.03, SD = 0.69), followed by material reuse (mean = 2.93, SD = 0.61) and improved resource efficiency (mean = 2.93, SD = 0.80). Pollution reduction (mean = 2.87) and contribution to sustainable urban development (mean = 2.82) were also strongly endorsed, while perceived long term cost reduction (mean = 2.75, SD = 0.84) and, most notably, perceived improvement in urban environmental quality (mean = 2.65, SD = 0.95), which combined the lowest mean and the highest standard deviation of any item across the three scales, received comparatively weaker and more variable endorsement.

Table 4
Mean and Standard Deviation Responses on Sustainable Waste Management Strategies

Statement	Mean	SD	Decision
1. Waste reduction strategies help minimise environmental pollution	2.87	0.60	Agreed
2. Recycling of construction materials improves environmental sustainability	3.03	0.69	Agreed
3. Reuse of construction materials reduces demand for new raw materials	2.93	0.61	Agreed
4. Sustainable waste management practices improve resource efficiency	2.93	0.80	Agreed
5. Sustainable waste management practices reduce construction costs in the long run	2.75	0.84	Agreed
6. Sustainable waste management practices improve environmental quality in urban areas	2.65	0.95	Agreed
7. Sustainable waste management supports sustainable urban development	2.82	0.70	Agreed
<i>Decision rule: Mean $\geq$ 2.50 = Agreed; Mean $<$ 2.50 = Disagreed</i>			

Practitioners endorse the same practices as effective strategies that they report as constrained in practice, a pattern that reveals an attitude-behaviour gap rather than ignorance of what works. Recycling and reuse were rated the most effective strategies, aligning with [7] identification of recycling as central to diverting waste from landfill, and with Circular Economy Theory's emphasis on retaining material value through extended use [37, 9]. That these strategies are simultaneously the most endorsed and, per Table 3, among the most constrained by infrastructure gaps, underscores that the barrier to better outcomes in Ibadan is primarily structural rather than attitudinal.

The comparatively weak and highly variable endorsement of visible improvement in urban environmental quality is this section's more sobering finding, suggesting that whatever gains individual sites achieve through recycling or reuse have not yet aggregated into a perceptible citywide effect. This is consistent with Min et al.'s [21] observation that project-level sustainability gains require coordinated policy, adequate infrastructure, and sufficient scale to register at the urban level, conditions that, on this evidence, remain largely absent in Ibadan.

4.5 Inferential Statistical Analysis

4.5.1 Chi-Square Test of Association

Chi-square tests examined associations between demographic variables and practice adoption (Table 5). A significant association emerged between years of experience and recycling practice adoption ($\chi^2 = 22.156$, $df = 9$, $p = .008$, Cramer's $V = 0.451$). The remaining three variable pairs, profession by segregation, project type by plan implementation, and position by material reuse, were not significant.

Table 5
Chi-Square Test Results for Demographic Variables and Waste Management Practice Adoption

Variable Pair	χ^2	df	p-value	Cramer's V	Interpretation
Profession × Waste Segregation	18.742	12	0.095	0.324	Not significant
Experience × Recycling Practice	22.156	9	0.008*	0.451	Significant
Project Type × Waste Management Plan	14.893	9	0.096	0.287	Not significant
Position × Material Reuse	16.234	12	0.181	0.308	Not significant
*Significant at $p < 0.05$					

The significant association between experience and recycling adoption is consistent with Yakubu et al. [17], who identified experience as a determinant of waste management effectiveness, and the moderate effect size indicates a substantively meaningful, not merely statistical, relationship. That profession does not predict segregation practice suggests segregation behaviour is shaped by site-level conditions rather than professional background, consistent with [3], who located the roots of poor segregation in general awareness gaps rather than in any single professional group. With only 60 respondents distributed across variables carrying up to seven categories, however, several cells in these contingency tables are likely to fall below the conventional minimum expected count of five, which inflates the risk of an unstable chi-square statistic and should temper confidence in both the significant and the non-significant results reported here.

4.5.2 Multiple Regression Analysis

The multiple regression examined predictors of sustainable practice adoption, entering years of experience, professional role, project type, and organisational position as independent variables against a composite sustainable practice score (Table 6). The model was statistically significant, $F(4, 55) = 9.634$, $p < .001$, and explained 41.2% of variance in adoption ($R^2 = 0.412$, adjusted $R^2 = 0.368$). Years of experience ($\beta = 0.312$, $p = .005$) and professional role ($\beta = 0.267$, $p = .017$) were significant predictors; project type and organisational position were not. Variance inflation factors remained below 2.0 for all predictors, indicating no material multicollinearity.

Table 6
Multiple Regression Analysis for Sustainable Practice Adoption

Predictor Variable	B	SE B	β	t	p-value	VIF
(Constant)	1.894	0.342		5.538	0.000	
Years of Experience	0.187	0.064	0.312	2.922	0.005*	1.124
Professional Role	0.143	0.058	0.267	2.465	0.017*	1.189
Project Type	0.098	0.072	0.156	1.361	0.179	1.342
Organizational Position	0.112	0.069	0.184	1.624	0.110	1.278
$R^2 = 0.412$, Adjusted $R^2 = 0.368$, $F(4,55) = 9.634$, $p < 0.001$						

The significant contribution of years of experience supports Min et al. 's [21] argument that accumulated practical knowledge enhances the adoption of sustainable strategies, while the significance of professional role aligns with [19], who found that professionals directly involved in material estimation and procurement exert greater influence over waste outcomes than those in peripheral roles, and is broadly consistent with evidence that construction professionals' knowledge of waste management planning, recycling and legal requirements is itself a significant predictor of implementation behaviour [42]. Together, these results support [6] proposition that professional capacity building, rather than structural reform alone, is a necessary condition for sustainable waste management. The non-significance of project type and organisational position reinforces this reading: it is the individual professional, not the kind of project or the rank held within a firm, that predicts sustainable behaviour, pointing policy attention toward person-level training rather than project-specific mandates. A caveat, developed in Section 3.9, is that these variables are multi-category nominal predictors entered without a stated reference category, which limits how precisely the direction of effects can be read from the coefficients alone.

4.5.3 Factor Analysis

Principal component analysis with varimax rotation conducted identified underlying dimensions of waste management practice. Sampling adequacy was confirmed by the Kaiser Meyer Olkin measure (0.712) and Bartlett's test of sphericity ($\chi^2 = 186.342$, $df = 21$, $p < .001$) (Table 7). Three components were extracted, together explaining 58.87% of total variance (Table 7a). Component 1 (34.46%), loading on material estimation, storage, and segregation, is labelled preventive practices; Component 2 (21.91%), loading on reuse and recycling, is labelled material recovery practices; and Component 3 (16.60%), loading on collection and disposal and on formal waste management plans, is labelled systematic management practices, a grouping consistent with Abd Rahim and Kasim's (2017) conceptual model, which similarly treats collection, disposal, and formal planning as a distinct, coordinating layer rather than isolated site activities. All primary loadings exceeded 0.69.

Table 7
Factor Analysis Results for Construction Waste Management Practices

Practice Item	Component 1	Component 2	Component 3	h ²
Proper material estimation	0.768	0.187	0.142	0.641
Proper on-site storage	0.723	0.243	0.098	0.592
Waste segregation	0.692	0.312	0.187	0.612
Material reuse	0.234	0.781	0.143	0.689
Recycling practices	0.187	0.742	0.214	0.632
Waste collection and disposal	0.156	0.218	0.823	0.744
Waste management plans	0.224	0.187	0.745	0.634

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalisation. Rotation converged in 5 iterations.

Table 7
a: Total Variance Explained by Extracted Components

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% Variance	Cumulative%	Total	% Variance	Cumulative%
1	2.845	40.643	40.643	2.412	34.457	34.457
2	1.276	18.229	58.872	1.534	21.914	56.371
3	0.987	14.100	72.972	1.162	16.601	72.972
4	0.764	10.914	83.886			
5	0.532	7.600	91.486			
6	0.387	5.529	97.015			
7	0.209	2.985	100.000			

That preventive, recovery, and systematic practices load onto separate components, rather than a single general factor, indicates that construction firms in Ibadan are not implementing waste management as an integrated system so much as a set of loosely coupled activities. This mirrors the fragmented implementation [9] describe elsewhere, and it maps onto the tiered structure of the Waste Management Hierarchy itself [3]: prevention, recovery, and systematic management occupy distinct rungs of that hierarchy in principle, and the factor structure suggests they also operate as distinct, weakly correlated practices on the ground in Ibadan. An intervention targeting one dimension, training on segregation, say, will therefore not automatically improve another, such as formal plan implementation, unless deliberately designed to do so. As noted in Section 3.9, a case-to-item ratio of roughly 8.6 to 1 is workable but not

generous, and this three-factor structure should be treated as provisional pending replication in a larger sample.

4.5.4 Logistic Regression Analysis

Binary logistic regression examined predictors of waste management plan implementation, coded yes or no, against years of experience, professional role, project type, organisational position, and recycling facility availability (Table 8). The model was statistically significant, $\chi^2 = 21.847$, $df = 5$, $p = .001$, with a Nagelkerke R^2 of 0.447 and correct classification of 78.3% of cases. The Hosmer Lemeshow test was not significant ($\chi^2 = 5.873$, $df = 8$, $p = .662$), indicating adequate model fit. Years of experience ($Exp(B) = 1.958$, $p = .018$), professional role ($Exp(B) = 1.718$, $p = .043$), and recycling facility availability ($Exp(B) = 2.010$, $p = .007$) were significant predictors; project type and organisational position were not.

Table 8
Logistic Regression Analysis for Waste Management Plan Implementation

Predictor Variable	B	SE	Wald	df	p-value	Exp(B)	95% CI for Exp(B)
Years of Experience	0.672	0.283	5.642	1	0.018*	1.958	1.124–3.411
Professional Role	0.541	0.267	4.102	1	0.043*	1.718	1.018–2.901
Project Type	0.287	0.245	1.372	1	0.241	1.332	0.824–2.154
Organizational Position	0.324	0.259	1.565	1	0.211	1.383	0.832–2.299
Recycling Facilities Availability	0.698	0.261	7.152	1	0.007*	2.010	1.205–3.353
Constant	-2.341	0.876	7.143	1	0.008	0.096	
<i>Model Summary: -2 Log Likelihood = 64.328, Cox & Snell $R^2 = 0.324$, Nagelkerke $R^2 = 0.447$, Hosmer-Lemeshow $\chi^2 = 5.873$, $df = 8$, $p = 0.662$. Classification Accuracy = 78.3%</i>							

Recycling facility availability produced the largest effect of the three significant predictors, nearly doubling the odds of plan implementation, extending the descriptive finding that infrastructure is respondents' most cited constraint and supporting [20] argument that infrastructure availability plausibly enables systematic waste management rather than merely correlating with it. This is consistent with Alaka and Osman [13], who emphasised that weak enforcement and inadequate facilities jointly undermine construction waste management effectiveness in Nigeria, and with [7] contention that recycling infrastructure investment yields disproportionate returns for systematic uptake specifically. The cross-sectional design, however, means the direction of this relationship cannot be established from these data alone, and with only 60 cases across five predictors, the events per variable ratio is likely below the ten cases per predictor commonly recommended for stable estimates, so these coefficients should be treated as exploratory rather than confirmatory.

4.5.5 Convergence Across the Multivariate Models

The four inferential models converge on a consistent picture: professional experience and role, rather than project or organisational context, are the variables most consistently associated with sustainable practice adoption and formal plan implementation, while infrastructure availability is the strongest lever for moving a site from informal practice to formal planning. This convergence across the chi-square, regression, factor, and logistic models strengthens confidence in the substantive findings, even though the small sample and the categorical treatment of several predictors, discussed in Section 3.9, warrant caution in how precisely the coefficients should be trusted. However, this can be acceptable as this is coming from experience experts in the field.

4.6 Limitations of the Study

The results of these are limited by a number of factors. The sample size (60) was not probability sampled but rather purposive and snowball sampling; there was a lack of any statistical representation of the total population of construction workers in Ibadan, while the recruitment process may have resulted in respondents being drawn from similar circles, known as referral-based recruitment.

The cross-sectional design only takes snapshots of associations at one moment and does not allow for determining the direction of causality. No site audit or waste quantity measurement was conducted, and all data are self-reported, which can create social desirability bias, especially on the issue of compliance with the regulation.

No quantitative validity or reliability result was reported for the instrument, as outlined in Sections 3.7 and 3.8, and this would be corrected before further use. Although the number of cases to predictors in both the regression and logistic regression models is manageable, these models provide the coefficient estimates that are modest and should be considered exploratory until the results are replicated in a larger sample, especially in the logistic regression model.

Lastly, because the study was conducted in one city, the results should not be extrapolated to other cities without independent testing.

5. Conclusion and Recommendations

5.1 Conclusion

This study focused on construction waste management, the constraints to construction waste management and the solution to the sustainability problems of construction practitioners in Ibadan, Oyo state. It makes use of the information gathered from 60 experts, as well as descriptive and multivariate statistical analysis, and reveals that the construction sector is managing waste, albeit not in a uniform fashion and not often with a coordinating architecture to make waste management systematic. The extensive practice of recycling and formal collection services is fairly well developed, with on-site storage and formal planning less well developed: there is a good chance that the enterprise of a few individuals, predominantly driven by cost considerations, has taken hold more easily than the

organisational structures required to make it happen. The most significant barriers, identified as limited recycling facilities, poor material planning and lack of training, take precedence over weak enforcement or financial limitation, which brings policy focus more to capacity development and provision of infrastructure than to enforcement.

This picture is echoed by the multivariate analyses. The level of sustainable practice adoption and plan implementation is predicted by experience and professional role - not by project type or professional position in the organisation - and availability of recycling facilities is the strongest predictor of the existence of a plan. The three factors identified, preventive, recovery, and systematic practices, suggest that the waste management dimension of construction activity in Ibadan is underdeveloped, with each practice having only a limited impact on the others, which may account for the lack of a significant overall improvement in perceived environmental quality.

The foregoing evidence confirms the fact that construction waste management in Ibadan is still reactive and not strategic. To bridge that gap in the years to come will take cross-sectoral effort across government, industry, professional organisations and academic institutions, focused on the infrastructural and organisational integration that is not yet evident in practice, and not at any one constraint alone. In view of the sampling and design constraints outlined in Section 4.6, such conclusions should be considered a strong empirical basis for indicating the construction waste management profile of Ibadan and not as a definitive and generalisable assessment of it.

5.2 Recommendations

In light of the above, the following recommendations are made:

1. Dedicated construction waste recycling facilities in Ibadan, Oyo State, should be built, and existing Environmental laws should be enforced by the Oyo State Government and the Federal Ministry of Environment. For people who dump illegal waste, penalties and incentives for certified waste management plans should be set, as the availability of recycling facilities was identified as being influential in Section 4.5.4.
2. *Construction Companies and Contractors*: Construction companies and contractors in Ibadan should adopt and create project waste management plans at the beginning of a project. To avoid over-ordering, material estimation and procurement should be optimised, and onsite storage systems should be organised to reduce damage to materials.
3. *Training and Capacity Building*: Professional bodies, such as COREN, NIA and NIQS, need to develop and deliver focused waste management training to professionals and site workers, on sorting, recycling, reuse and regulatory compliance, as there is near universal consensus on poor training, as reported in Section 4.3.

4. *Sustainable practice*: University and polytechnic courses of construction-related courses should include concepts on construction waste management and circular economy in the curriculum to create future professionals with a sustainable approach.
5. *Public Private Partnerships*: The Ibadan city government, in view of the identified gap in recycling facilities in this study, should enter into partnership with the private waste management companies to make provision for recycling waste management and collection services in the active construction sites.
6. *Urban Planning Integration*: Sustainable waste management targets should be incorporated into the planning approval process of new development in Ibadan, not left to chance, as this would directly tackle integration issues identified from the factor analysis.

5.3 Suggestions for Further Studies

1. Long-term monitoring of the practice of construction waste management in Ibadan would reveal the effect of time on whether policy interventions can make a lasting impact or just short-term compliance.
2. Comparative studies that would compare waste management in large formal contracting firms with smaller informal contractors would help to clarify the effect of firm size and the formality of the firms in the cities of Nigeria on waste outcomes.
3. Future studies should incorporate aspects of the questionnaire with direct observations and waste audit techniques to derive objective measures which cannot be obtained from self-reports alone.
4. A study of the economic viability of the construction waste recycling business in Ibadan would help ascertain investment opportunities to fill the identified infrastructure gap here.

Declarations

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Author Contributions

O.B. is the sole author of this manuscript and is responsible for the study conception and design, data collection, analysis and interpretation, and drafting and revising the manuscript. The author read and approved the final version.

Competing Interests

There is no conflict of interest as this is sole authored

Data Availability Statement

The datasets generated and/or analysed during the current study are available with the author on reasonable request.

Ethics Approval

The Research Ethics Committee of Lead City University, Ibadan, Oyo State, Nigeria, granted ethical approval for this study, and all the procedures in the study were done in accordance with the ethical principles of the Declaration of Helsinki.

Consent to Participate

Informed consent was obtained from all the individual participants for participation in this study. Participation was voluntary, and respondents were informed of the study's purpose before completing the questionnaire. No personally identifying information was collected, and responses were treated as anonymous and used solely for academic purposes. Respondents could decline to answer any item or withdraw at any point during data collection without consequence.

Consent to Publish

Not applicable. This manuscript does not contain any individual person's data, images or identifying details in any form.

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Figures

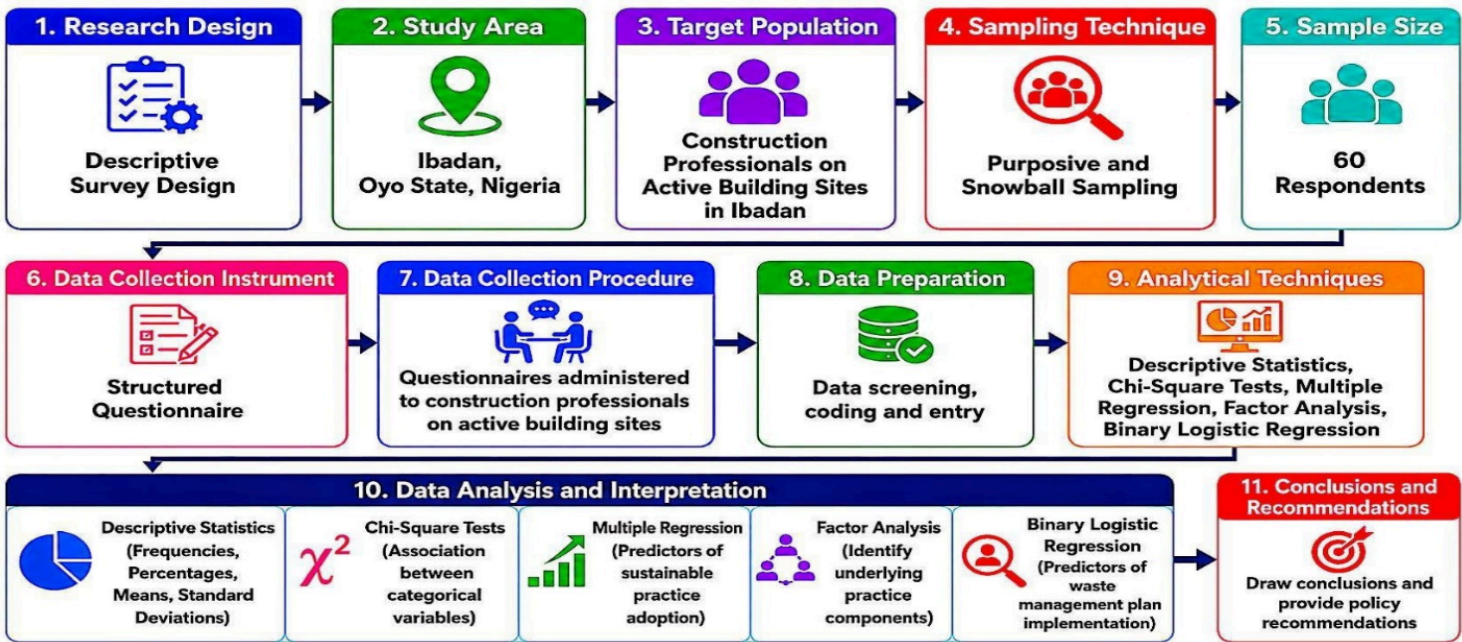


Figure 1

illustrates the methodological flow chart of the study.