Prioritising Materials Procurement and Construction Waste Management Attributes

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Abstract

Construction and demolition waste constitutes the largest municipal solid waste (MSW) globally with environmental concerns. However, waste management is not considered a priority objective in construction compared to time and cost. Therefore, construction practitioners' waste management priority is evaluated in this study. A review of the literature revealed waste management attributes from multiple perspectives. A questionnaire survey was adopted to solicit practitioners' contributions on their importance. Then, the attributes were prioritised and categorised into high, medium and low priorities using the Voting Analytical Hierarchy Process (VAHP). Empirical results indicate that the high priority materials procurement attributes were alliance with suppliers, a take-back clause in suppliers' agreement document, accurate material quantification, accurate material ordering, and just-in-time delivery (JIT) plan. Senior managers' early commitment to waste minimisation, effective communication among project participants, making subcontractors responsible for their waste, identifying recyclable materials and identifying reusable materials were high-priority attributes for managing waste in the construction stage. The findings of this study indicate areas where contractors should focus effort to improve waste management in the industry by collaborating with subcontractors and suppliers. Future studies should focus on developing frameworks that provide actionable means for implementing waste management attributes identified in this research.

Key words: Waste, Construction management, Sustainable cities and communities

Notation

e	confidence interval expressed as a decimal
no	sample size
p	worst-case percentage picking choice expressed as a decimal
w	total weight of each criterion or attribute at rank positions (i.e.) 1, 2, 3…n
ws	coefficient weight
z	standardised variable (confidence intervals)

1. Introduction

The life cycle of construction materials impacts the environment from extraction to disposal. Therefore, sustainable waste management cannot be ignored in construction due to globalisation and continuous demands for natural resources. Sustainability became a watchword after the Brundtland Commission in 1987, demanding sustainable conduct at individual, organisational, national, regional and global levels. Hence, waste management is an integral part of the overall sustainable construction that seeks to meet the need of the current infrastructural development without compromising future demand for natural resources. There is a need to prioritise waste management strategies as benchmarks for successful project management across the global construction industry for sustainable development, owing to the impacts of waste on the natural environment (Sev, 2009). However, most construction materials are usually wasted with minimal effort to minimise or reclaim them. The industry's waste accounts for about 40% of the total municipal solid waste (MSW) outputs globally (Esa *et al.,* 2017).

Studies have demonstrated waste output from different countries, creating awareness to drive the minimisation agenda (DEFRA, 2020; European Commission, 2015; The United States Environment Protection Agency, 2020). However, the disposal of waste to landfill is increasing in many parts of the world, notably in the developing countries of Sub–Saharan Africa (SSA) (World Bank, 2018). For instance, more than 78% of construction waste is disposed of indiscriminately or burnt in Ondo State, Nigeria (Adedeji et al., 2013). Many studies are usually focused on the causes of waste, while strategies for minimisation are seldom explored (Adeagbo *et al.,* 2016; Adewuyi *et al.,* 2014; Aiyetan and Smallwood, 2013; Dousman *et al.,* 2012; Idris *et al.,* 2015; Koo and Itodo, 2013; Wahab and Lawal, 2011). Meanwhile, no study has examined the practitioners' waste management priorities to help contractors minimise waste by focusing on the key strategies and plan for implementation. Further, there is a considerable effort to minimise waste in the construction stage (Lu and Yuan, 2011). However, waste management needs to be considered in multiple stages (Ekanayake and Ofori, 2004), particularly those with limited attention, such as the materials procurement stage (Ajayi and Oyedele, 2018). Therefore, this study intends to evaluate the Nigerian construction practitioners' waste management priorities in the materials procurement and construction stages to help contractors appreciate the key strategies.

This research article is divided into five sections, from the introduction to the conclusion. Section 1 is the background of the study. Section 2 reviews the literature and presents the conceptual framework (Figure 1) to help analyse practitioners' waste management priorities. Section 3 outlines the research methods. Section 4 presents the results, and 5 discusses the findings. Finally, the research conclusion is presented in section 6, including recommendations for practice and future studies.

2. Literature Review

Waste management hierarchy is fundamental to sustainable waste management (Aadal *et al.,* 2013; Lu and Yuan, 2011; Yuan and Shen, 2011). The model's key objective is to help prevent and reduce waste at the source substantially, and any amount generated can be reused or recycled. Further, it promotes materials recovery against end-of-pipe treatment, which is harmful to the ecosystems. Research efforts have been made to provide waste management solutions for construction practitioners using the model as a motivating factor. For example, Ling and Nguyen (2013) identified several ways waste could be minimised in Ho Chi Minh City, Vietnam. These are (1) employment of subcontractors with waste management ability, (2) training, (3) audit and effective supervision, (4) sequence activities to reduce damage to completed work, (5) set level of wastage allowable, and enforce through punishments and reward systems. Doust et al. (2021) explored critical strategies for construction waste management in the Australian construction industry and identified regulatory change with policies and procedures focusing on the procurement stage. According to Omer *et al.* (2022), providing temporary skip, identify activities that produce recyclable materials, and developing policies will improve construction waste recycling. Government legislature, employees' training, construction company waste management policy, financial reward and incentives are key to reducing waste in Chennai, India (Janani *et al.,* 2022). Other important measures are awareness creation, planning, implementation and monitoring (Elena *et al.,* 2022).

These waste management strategies are a valuable reference for researchers who intend to develop frameworks or models for sustainable waste management. For example, a world Bank (2005) report stressed that the waste management model should be adopted to promote effective and sustainable waste management. Although scholars have identified several waste management strategies using the model to encourage reducing, reusing and recycling construction waste, their relative priorities are not necessarily universal.

2.1. Conceptual Framework to Help in the Analysis of Practitioners' Waste Management Priorities

A literature search was conducted to identify key criteria for waste management in materials procurement and construction activities. The literature shows several criteria through which effective materials procurement and construction waste management can be achieved, such as top management support (Bakshan *et al.,* 2017; Dainty and Brook, 2004; Ling and Lim, 2002; Ling and Nguyen, 2013; Mak *et al .,* 2019; Teo and Loosemore, 2001; Tam and Tam, 2008). Top management support systems are means for improving competency for effective waste management. Another criterion is contractual clauses which can influence positive partnerships between contractors and employees, such as subcontractors and suppliers, to aid waste minimisation (Ajayi *et al.,* 2017a; Barritt, 2016; Cha *et al.,* 2009; Ling and Nguyen, 2013; Lu *et al.,* 2016; Nagapan *et al.,* 2012; Poon and Jaillon, 2004; Wrap, 2009; Wu *et al.,* 2017). Contractual obligations allow subcontractors and suppliers to collaborate with contractors to implement good waste management as a duty of care.

From the materials procurement perspective, low waste purchasing (Ajayi, 2017b; Bakchan *et al.,* 2019; Poon *et al.,* 2004; Saez *et al.,* 2013; Tam, 2008; Wang *et al.,* 2008; Yu *et al.,* 2021) and efficient delivery management (Afolabi *et al.,* 2018; Ajayi and Oyedele, 2018; Bossink and Brouwers, 1996; Kofoworola and Gheewala, 2009; Poon et al., 2004) influences waste minimisation. Moreover, low waste purchasing and delivery of construction materials are fundamental components of supply chain management for just-in-time delivery of materials and inventory management to avoid damage, spoilage, and other factors (Mohopadkar and Patil, 2017).

Further, implementing a site waste management plan (SWMP) is important in the construction phase. A site waste management plan enables the planning and documentation of waste types, quantity generated, and management options (Gangolells *et al.,* 2014; Mcdonald and Smithers, 1998; Oladiran, 2009; Price, 2010; Shiers *et al.,* 2014; Tam, 2008). SWMP can be used to benchmark a project against others for waste management improvement. Additionally, adopting low-waste techniques in construction is a hard measure for reducing waste in projects (Jaillon *et al.,* 2009; Poon *et al.,* 2003; Umar *et al.,* 2017; Yahya and Boussabaine, 2006).

Therefore, in this study, the waste management criteria that requires attention from the industry practitioners are encompassed under four categories for materials procurement: (1) top management support for procurement, (2) procurement clauses, (3) low waste purchasing and (4) efficient delivery management. Similarly, for the construction stage, they are grouped under four categories: (1) top management support for construction, (2) construction clauses, (3) site waste management plan and (4) the use of low waste construction techniques. For each component, several attributes were also identified and grouped in Tables 1 and 2, representing the research's conceptual framework that captures the contexts in which waste management priorities in materials procurement and construction activities can be analysed.

Table 1: Criteria and attributes factors influencing materials procurement waste management

Criteria	Attributes	References
Top management support for procurement	(1) Waste management guideline for procurement personnel	Abd Hamid *et al.,* 2016
	(2) Alliance with suppliers	Dainty and Brooke 2004; Cheng and Mydin, 2014
	(3) Involve a competent purchase manager in procurement activities	Tunji-Olayeni *et al.,* 2017; Ahad *et al.,* 2017
	(4) Periodic training of procurement personnel on waste management strategies	Al-Hajj and Hamani, 2011; Tunji-Olayeni *et al.,* 2017; Ahad *et al.,* 2017
	(5) Provision of stock control measures	Dainty and Brooke, 2004; Williams and Turner, 2011;
Procurement clauses	(1) Agreement with suppliers on waste management strategies	Dainty and Brooke 2004
	(2) Consistency in suppliers' agreement document	Domingo *et al.,* 2009
	(3) Supplier flexibility in providing a smaller quantity of materials	Dainty and Brooke, 2004; Cheng and Mydin, 2014; Ajayi and Oyedele, 2018
	(4) Supplies to supply quality and durable materials	Esin and Cosgun, 2007; Nagapan *et al.,* 2011; Al-Rifai and Amoudi, 2016
	(5) Take-back clause in suppliers' agreement document	Ajayi *et al.,* 2017
Low waste purchasing	(1) Accurate material ordering	Memon et al., 2014 ; Ajayi *et al.,* 2017
	(2) Accurate material quantification	Lee *et al.,* 2016
	(3) Purchase of high-quality products	Nagapan *et al.,* 2011; Al-Rifai and Amoudi, 2016
	(4) Purchase of maintainable materials	Begum *et al.,* 2007; Wan Abdullah and Mohd Ridzuan, 2008; Hussien *et al.,* 2016;
	(5) Materials substitution	Zaman and Lehmann, 2013; Luciano *et al*., 2020
	(6) Purchase of secondary materials	Wang et al., 2015; Liu et al., 2020
Efficient delivery	(1) Adequate site access for delivery vehicles	Osmani *et al.,* 2008; Poon *et al.,* 2013
	(2) Careful material handling to avoid breakage	Navon and Berkovich, 2006 Shakantu *et al*., 2008
	(3) Just-in-time delivery (JIT) of plan	Akintoye, 1995; Dainty and Brooke, 2004
	(4) Safe storage of materials onsite	Begum *et al.,* 2010; Fadiya *et al.,* 2014

Table 2: Criteria and attributes factors influencing construction waste management

Criteria	Attributes	References
Top management support for construction	(1) Active site supervision	Cha et al., 2009; Udawatta *et al.,* 2015; Bakchan and Faust, 2019
	(2) Adequate waste reduction investment	Chen and Wong, 2002; Tam et al., 2007; Jia et al., 2017
	(3) Effective communication among project participants	Kulatunga *et al.,* 2006; Yuan, 2013; Li and Du, 2015
	(4) Motivating employees to minimise waste	Teo and Loosemore, 2001; Chen and Wong, 2002; Chen *et al.,* 2002; Osmani *et al.,* 2006; Li and Du, 2015
	(5) Periodic training of site employees on waste management strategies	Oyedele *et al.,* 2003; Kulatunga *et al.,* 2006; Zhang *et al.,* 2012 Park and Tucker, 2017;
	(6) Senior managers early commitment to waste minimisation	Teo and Loosemore, 2001; Lingard *et al.,* 2000; Tan *et al.,* 2011;
Construction clauses	(1) Incentive clause for effective waste management practice	Poon et al., 2013; Ling and Nguyen, 2013; Lu et al., 2016
	(2) Making subcontractors responsible for their waste	Tam and Tam, 2008; Ann *et al.,* 2013
	(3) Site waste management policy for site operatives	Begum *et al.,* 2007; Dania *et al.,* 2007
	(4) Waste target clause in subcontractors' agreement document	Tam and Tam, 2008; WRAP, 2009; BREEAM 2020
Site waste management plan	(1) Adequate space for material movement onsite	Yuan et al., 2011; Mortaheb and Mahpour, 2016; Abarca-Guerrero et al., 2017; Yuan *et al*., 2018
	(2) Forecasting the emerging waste streams	WRAP, 2009; Lu *et al.,* 2016; Akinade *et al.,* 2016
	(3) Identifying recyclable materials	Tam and Tam, 2006; Tam, 2011; Katz and Baum, 2011; Yu *et al.,* 2021
	(4) Identifying reusable materials	Tam, 2011; Acchar *et al.,* 2013; Park and Tucker, 2017
	(5) Segregating waste materials into categories	Poon et al., 2004; Montero *et al.,* 2010; Lu and Yuan, 2012
Low waste techniques	(1) Adopting the right work sequence	Dania et al., 2007; Ling. and Nguyen, 2013
	(2) Adopting prefabricated building components	Poon *et al.,* 2003; Tam *et al.,* 2005; Chiang *et al.,* 2006; Tam and Tam, 2006; Tam *et al.,* 2006; Shen *et al.*, 2009
	(3) Use of appropriate construction equipment	Muleya and Kamalondo, 2017; Esa *et al.,* 2017
	(4) Maximise use of joint systems instead of glueing	Akinade et al., 2017; Ajayi et al., 2017
	(5) Use of deconstructable materials	Wang, 2018; Bertino *et al.,* 2021
	(6) Use of reusable formwork and falsework	Lau *et al.,* 2008; Lu and Yuan, 2010; Lu *et al.,* 2011
	(7) Use of steel scaffolds	Wang *et al.,* 2014; Muleya and Kamalondo, 2017

3. Methods

The methods adopted in this study comprise verification of the conceptual framework, pilot testing, a quantitative survey and the voting analytical hierarchy process (VAHP). Verifying the conceptual framework means checking that the framework can fulfil waste management requirements from the perspectives of the materials procurement and construction stages. Following Asah-Kissiedu (2019); Lam *et al.,* (2017), twelve academic construction experts of Nigerian origin were invited and recruited through networks of personal contacts to verify the criteria, attributes and grouping. All the experts have a PhD as a minimum qualification and are affiliated with one or two professional bodies. The experts were positive that the conceptual framework can fulfil waste management requirements and that the attributes' grouping under each criterion is legitimate. Therefore, the validation of the conceptual framework helps determine the importance and robustness of the criteria and attributes in fulfilling waste management objectives based on the research scope.

A survey was designed using the Qualtrics software platform because of its efficiency in data management (Molnar, 2019). In developing the survey, the rank-order type was chosen to compare lists of waste management items based on participants' priorities and preferences. Rank order was found appropriate for this study for its straightforward statistical analysis and application in construction project management studies (Lam *et al.,* 2017). The survey was pilot-tested with twelve construction practitioners to identify any potential error or difficulty in completing it. All the participants suggested that the questionnaire was meaningful and unambiguous and had no difficulty completing it.

Following the pilot test, the survey was ready to be distributed to the main participants online. A search was conducted to find eligible construction industry practitioners through members of professional bodies online directory of Nigerian industry professionals from the link (https://educeleb.com/professional–bodies–in–nigeria–websites/). A similar approach has been adopted in previous studies (Manu, 2012; Ogunmakinde, 2019). Therefore, by adopting purposive sampling (Mbote *et al.,* 2016; Shakantu *et al.,* 2008), many engineering and construction professionals who listed their email addresses or phone numbers on the website were contacted for participation.

Also, a chain referral technique was used in a quest to involve more participants in the survey for a reasonable response rate. Therefore, some of the initially recruited participants assisted in recruiting other eligible participants. According to Penrod *et al.* (2003), a chain referral technique can involve hard-to-reach eligible survey participants. All invited participants were required to have a minimum of one year in construction practice to ensure a good experience and a minimum of Ordinary National Diploma (OND) academic qualifications to be eligible. Abuja, Lagos and Port Harcourt were selected as the study area for geographical representation and significant construction activities. The sample size was estimated because there is no publicly available data on the total number of the study population. Therefore, Creative Research Systems (2016) was used to calculate the sample size using Cochran (1977) formula below.

$$\mathbf{n_o} = \frac{Z^2 p(1-p)}{e^2}$$

Where:

n_o = sample size

z = standardised variable (confidence intervals)

p = the worst-case percentage picking choice expressed as a decimal

e = confidence interval expressed as a decimal Sample size decisions

Based on most studies, a 95% confidence level (Creative Research Systems, 2016; Sweis *et al.,* 2021) was assumed where z = 1.96 at (α=0.05). Furthermore, to balance the level of precision, a confidence interval (e) of 10% was also assumed for this study. Finally, a 50% or 0.5 picking choice (p) in a worst-case was assumed to determine the appropriate sample size. Therefore, the sample size of this study was calculated thus:

$$\mathbf{n_o} = \frac{1.962 \times 0.5(1 - 0.5)}{0.1^2} = 96$$

The required sample size for the survey is 96 construction practitioners. However, it has been reported that a response rate between 20–30% is common and acceptable in studies adopting a questionnaire survey for data collection (Akintoye, 2000; Dulami *et al.,* 2003). Therefore, to achieve a minimum of 25% response rate, the sample size was adjusted to deal with nonresponse in the study. Thus, this study assumed a conservative response rate of 25% to arrive at the sample size of the surveyed as follows:

$$\textbf{\textit{Final sample size}} = \frac{\text{Initial } n_o}{\text{Common response rate}}$$

$$\mathbf{n_o} = \frac{96}{0.25}$$

Research sample = 384 practitioners

This sample size was doubled (768) following Manu (2012) to improve the number of responses and further reduce the effect of the nonresponse rate common in an online survey (Nair and Adams, 2009). The sample size for this study is large enough compared to similar studies (Adeagbo *et al.,* 2016; Adewuyi *et al.,* 2014). A link to the online survey, including an invitation letter and a consent form, was emailed to the 768 selected construction practitioners in Nigeria. As a result, 211 persons responded and completed the survey adequately, representing a response rate of ~ 28%, which is reasonable (Aderibigbe *et al.,* 2017; Saidu and Shakantu, 2017).

3.1. Data Analysis Method

The VAHP model, proposed by Liu and Hai (2005) and improved by Hadi-Vencheh and Niazi-Motlagh (2011), was adopted to determine the weighted priority of materials procurement and construction waste management attributes. The VAHP model inherited Saaty (1980) AHP hierarchical model for multiple criteria decision making and Noguchi *et al.* (2002) strong ordering model by data envelopment analysis (DEA).

Using the VAHP, each participant can vote from 1 to S (S≤R), where R is the number of attributes in a criterion, and S is the rank order (Liu and Hai, 2005). In this study survey, S varies in the measurement scale based on the number of attributes in a criterion (S=R). Therefore, respondents were asked to rank their most preferred waste management strategy in ascending order from 1, 2, 3...n. Hence, the most important attributes should be scored number 1, compared to other attributes and the second most important number 2, in that order. Based on the variable Likert measurement scale, participants were informed to assign the numbers on the boxes provided on the right-hand side of each question.

From equations 1 and 2 (Hadi-Vencheh and Niazi-Motlagh, 2011) the coefficient weights of the rank positions presented in Table 4 were calculated using the Microsoft Excel spreadsheet. Thus, the global weight of each waste management attribute is computed and categorised into priorities.

$$w_1 \geq 2w_2 \geq \cdots \geq S w_s \geq 0 \qquad \text{Eq. 1}$$

and

$$\sum_{s=1}^{S} w_s = 1 \qquad \text{Eq. 2}$$

Where:

w_s = coefficient weight
w = Total weight of each criterion or attribute at rank positions (i.e.) 1, 2, 3…n

3.2. Categorising the Attributes into Priorities

To group the attributes into priority categories, a priority point was given to the attributes based on their weights (Kim and Kumar, 2009). Therefore, from the global weight score results in tables 5 and 6, the attributes are grouped in categories to signify how the stakeholders prioritised them to help contractors understand the waste management priorities of the industry practitioners to plan for implementation actions based on available resources or circumstances. A weighted score of < 0.040 is considered a low priority category, 0.041>0.050 medium, 0.051 and above is a high priority category. Therefore, in tables 5 and 6, the attributes' priorities are limited to three (Georgopoulou *et al.,* 2003). Schema for prioritising the waste management attributes is presented in Figure 1.

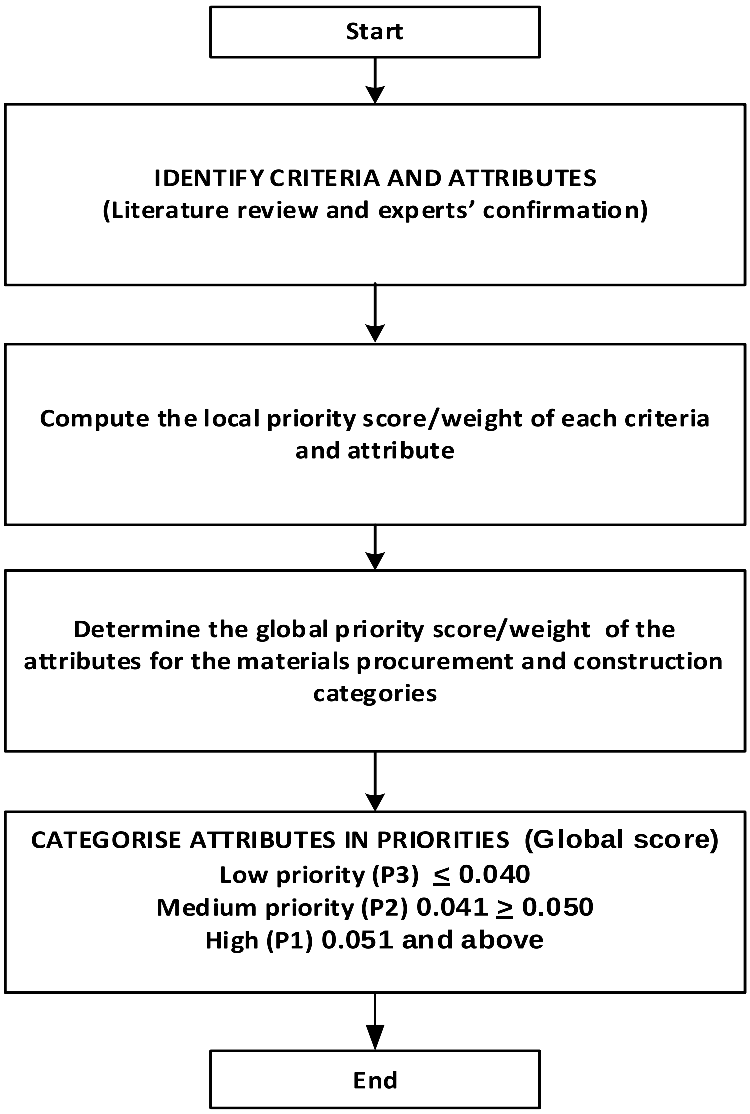

Figure 1: Schema for prioritising the waste management attributes

4. Results

4.1. Respondents' Characteristics

Table 3 summarised the data distribution patterns of respondents concerning their profession/job roles, highest education qualifications, number of years of experience and professional body affiliation using percentages (%) and frequency (n). All the participants indicated their job/professional roles. The results show that all the participants are construction industry professionals confirming their eligibility to participate in the survey. Project managers account for the highest (48), close to a quarter of participants. At the same time, structural engineers and procurement managers were the least (20) respondents each. The results of the highest qualification indicate that all the participants met the minimum qualification, which means they are educated enough to provide the necessary information for the study. Bachelor's degree holders are 91 in frequency distributions, almost half of the respondents, while PhD has the least (14) respondents. Likewise, the results show that most participants who answered the research question have between 6-10 years of experience, accounting for almost half (100) of the respondents according to the frequency distributions.

Table 3: Summary of Respondents' Demography

Demography	Groups/Labels	Frequency	Percentage (%)
Profession/job role	Project managers	48	23
	Civil engineers	40	20
	Quantity surveyors	32	15
	Mechanical engineers	30	14
	Procurement managers	20	9
	Structural engineers	20	9
	Site Supervisors	21	10
	Other	–	–
Highest qualification	Bachelor's degree/BEng	91	43
	Higher National Diploma	46	22
	Master's Degree	38	18
	Ordinary National Diploma	22	10
	PhD	14	7
	Other	–	–
Level of experience (years)	1–5	36	17
	6 –10	100	47
	11 –15	55	26
	16 –20	15	7
	Above 20	5	3
Professional body affiliation	The Council for the Regulation of Engineering in Nigeria (COREN)	67	32
	The Council of Registered Builders of Nigeria	53	25
	Nigerian Institute of Quantity Surveyors (NIQS)	44	21
	Nigerian Institute of Building (NIOB)	43	20
	Other	4	2

In comparison, only 5 respondents have above 20 years of experience, the least. Thus, all the respondents met the minimum qualification for participation. Finally, the results indicate that participants belong to professional bodies related to construction and engineering active in Nigeria, showing they have a certain level of expertise in their professions/job roles. From the frequency analysis, respondents affiliated with COREN are nearly a third of participants (67), which accounts for the highest, while only (4) are those in Nigeria Society of Engineers (NSE), which is the least.

Table 4: The Coefficient *ws* for different rank orders

Formulae	Number of ranking positions	Criteria	Attributes	Coefficient w_S
$1 \geq 2\ 2 \geq \cdots \geq w \geq 0$ $\sum = 1$ $=1$	7		✓ Low waste techniques	w1 0.3857 w2 0.1928 w3 0.1286 w4 0.0964 w5 0.0771 w6 0.0643 w7 0.0551
	6		✓ Top management support (construction) ✓ Low waste purchase management	w1 0.4082 w2 0.2041 w3 0.1361 w4 0.1021 w5 0.0816 w6 0.0680
	5		✓ Site waste management plan ✓ Top management support (procurement) ✓ Procurement clauses	w1 0.4380 w2 0.2190 w3 0.1460 w4 0.1095 w5 0.0876
	4	✓ Materials Procurement ✓ Construction	✓ Construction clauses ✓ Efficient delivery management	w1 0.4795 w2 0.2398 w3 0.1598 w4 0.1199

4.1. Results of the VAHP

In the fifth column (Tables 5 and 6), the respondents' priority voting survey establishes the relative importance of materials procurement and construction waste management attributes based on the global priority rank. In the sixth column (Table 5), the categorisation of twenty attributes across the criteria for materials procurement showed that alliance with suppliers, a take-back clause in suppliers' agreement document, accurate materials quantification, accurate material quantification and just-in-time delivery (JIT) plan are within the high priority category for materials procurement waste management. Other attributes are within the medium or low priority categories. In the sixth column (Table 6), senior managers' early commitment to waste minimisation, effective communication among project participants, making subcontractors responsible for their waste, identifying recyclable materials and identifying reusable materials are in the high priority category. Therefore, out of the twenty-two attributes of construction criteria categories, only six are within the high priority threshold, while others are within the medium or low priority ranks.

Table 5. Weighted importance of materials procurement waste management attributes (*Wi*)

Criteria	Weight (*Wi*)	Attributes	Weight (*Wi*)	Global Weight (*Wi*)	Priority
Top management support for procurement	0.245	Involve a purchase manager in procurement activities	0.191	0.047	Medium
		Provision of stock control measures	0.185	0.045	Medium
		Periodic training of procurement personnel on waste management strategies	0.181	0.044	Medium
		Alliance with suppliers	0.269	0.066	High
		Waste management guidelines for procurement personnel	0.173	0.040	Low
Procurement clauses	0.258	Take-back clause in suppliers' agreement document	0.311	0.080	High
		Consistency in suppliers' agreement document	0.154	0.040	Low
		Suppliers to supply quality and durable materials	0.191	0.049	Medium
		Agreement with suppliers on waste management strategies	0.188	0.049	Medium
		Suppliers to provide materials in a flexible amount	0.156	0.040	Low
Low waste purchasing	0.304	Purchase of secondary materials	0.149	0.045	Medium
		Purchase of maintainable materials	0.138	0.042	Medium
		Accurate materials quantification	0.220	0.067	High
		Purchase of high-quality products	0.150	0.046	Medium
		Accurate material ordering	0.202	0.061	High
		Material substitution	0.141	0.043	Medium
Efficient delivery	0.194	Adequate site access for delivery vehicles	0.250	0.049	Medium
		Careful materials handling to avoid breakage	0.224	0.043	Medium
		Just-in-time delivery (JIT) plan	0.278	0.054	High
		Safe storage of materials onsite	0.248	0.048	Medium

Table 6. Weighted importance of construction waste management attributes (*Wi*)

Criteria	Weight (*Wi*)	Attributes	Weight (*Wi*)	Global Weight (*Wi*)	Priority
Top management support for construction	0.297	Senior managers early commitment to waste minimisation	0.221	0.066	High
		Periodic training of site employees on waste management strategies	0.154	0.046	medium
		Adequate waste reduction investment	0.123	0.037	low
		Active site supervision	0.125	0.037	low
		Motivating employees to minimise waste	0.166	0.049	medium
		Effective communication among project participants	0.211	0.062	High
Construction clauses	0.189	Waste target clause in the subcontractors' agreement document	0.260	0.049	medium
		A site waste management policy for site employees	0.183	0.035	low
		An incentive clause for effective waste management practice	0.251	0.047	medium
		Making subcontractors responsible for their waste	0.305	0.058	High
Site waste management plan	0.267	Adequate space for material movement onsite	0.150	0.040	Low
		Identifying recyclable materials	0.285	0.076	High
		Forecast the emerging waste stream	0.186	0.050	Medium
		Segregating waste materials into categories	0.183	0.049	Medium
		Identifying reusable materials	0.194	0.052	High
Low waste techniques	0.244	Maximise use of joint system instead of gluing	0.144	0.035	Low
		Use of deconstructable materials	0.130	0.032	Low
		Adopting the right work sequence	0.114	0.028	Low
		Use of steel scaffolds	0.105	0.027	Low
		Adopting prefabricated building components	0.201	0.049	Medium
		Use of reusable formwork and falsework	0.161	0.039	Low
		Use of appropriate construction equipment	0.145	0.035	Low

5. Discussion

5.1. Materials Procurement Attributes

Alliance with suppliers is widely considered a critical success factor of supply chain management for improving waste management performance. The findings support Dainty *et al*. (2004) that developing alliances with suppliers and recycling companies is the most important waste management attribute contributing to improved supply chain management in construction. The findings also support Bankvall *et al*. (2010) that strategic supplier alliances would reduce waste and improve the quality of the supply chain. The findings, therefore, encourage the need for commitment and a stronger relationship between clients/contractors and material suppliers.

Take-back clause in the suppliers' agreement document is consistent with previous studies, indicating that the take-back arrangement with suppliers is an important measure of waste minimisation in materials procurement. For instance, through the subjective opinion of the UK design and construction firms, Ajayi *et al*. (2017b) found that commitment to the take-back scheme is the most important procurement attribute. The finding is consistent with Mortaheb and Mahpour (2016), who identified take-back policies as the most important procurement attribute under supplier selection management in the Iranian construction industry. However, an earlier study by Al-Hajj and Hamani (2011) found that a take-back arrangement with suppliers is the ninth most important procurement attribute for waste minimisation in the UAE construction industry. Considering this attribute as a high priority for waste minimisation would mean extending waste management responsibility to suppliers to minimise excess materials delivered on construction sites. Thus, it would require a prior agreement with suppliers, thereby the importance of including this measure in their contractual arrangement.

Accurate materials quantification agrees with (Li *et al.,* 2016), who proposed that enhancing estimation accuracy through levels of detail and experts' knowledge could lead to better materials management in construction. It explained that if buyers fail to follow specifications in the design documents or there is an error in specification, the outcome is usually over-ordering or purchasing products that do not comply with specifications. In that case, excess materials could be delivered on construction sites if quantity take-off is not accurately done (Muhwezi *et al.,* 2012). The findings demonstrated that understanding the scope of a project before purchasing materials cannot be overemphasised, as acknowledged in the RIBA Plan of Work 2020.

Accurate material ordering is in concordance with (Faniran and Caban, 1998), who found that over-ordering materials usually impacts waste generation on construction sites. Over-ordering of materials usually begin with mistakes in quantity take-offs and waste allowance meant to cover unavoidable losses (Hassan *et al.,* 2012). It, therefore, brought into focus to pay special attention to materials dimension to minimise offcuts. The findings imply that effort should be made to order materials in smaller quantities. This would mean that contractors should look for environmentally motivated suppliers ready to supply materials in smaller quantities (Ajayi and Oyedele, 2018; Cheng and Mydin, 2014; Dainty and Brooke, 2004).

The just-in-time delivery (JIT) plan agrees with (Al-Hajj and Hamani, 2011) that timely delivery of materials on construction sites is one of the most important strategies implemented in the UAE construction industry, which helps them minimise materials waste. The authors acknowledged that less waste is produced when the required materials are supplied to a construction site for work rather than stockpiling them. The findings buttressed (Dainty and Brooke, 2004), who maintained that timely materials delivery would minimise the time of materials storage and the potentiality of double handling and over-ordering. As a high-priority attribute, this would mean that materials will not be subjected to frequent handling, poor weather conditions, and risks of theft/vandalism will be minimised. In addition, the findings brought into focus a need to forecast materials demand accurately and use a faster delivery route to deliver construction materials on sites.

5.2. Construction Attributes

Senior managers' early commitment to waste minimisation is consistent with the findings of previous studies. According to Papargyropoulou *et al.* (2011); Teo and Loosemore (2001), senior managers' awareness and commitment improve waste management performance. However, contrary to the current findings, there is evidence that senior managers are more interested in projects' time and cost performance than waste management (Begum et al., 2009). This supports the common belief that waste management is not usually a top priority for senior managers like cost and time. Nevertheless, the current finding would mean that senior managers must see effective waste management as a top priority to drive sustainable waste management. Their visible involvement and commitment can play an important role in reducing waste in the industry. It further revealed the need for a top-down approach to waste management in construction where senior managers champion the cause of changing the industry's poor waste management culture (Teo and Loosemore, 2001).

Effective communication among project participants aligns with Constructing Excellence (2004) on the importance of stakeholders being aware of project requirements for waste minimisation. The findings would remind contractors to adopt efficient communication practices, such as good quality documentation and feedback from site operatives on waste management performance (Lingard et al., 2001). It focused on the importance of stakeholders sharing new ideas and experiences from past projects to improve strategies and create awareness about sustainable waste management in the industry.

Making subcontractors responsible for their waste is consistent with several studies on the need for waste producers to be held accountable for the waste they produce (Lu *et al.,* 2015; Poon *et al.,* 2013). It, therefore, reinforced the concept of extended producer responsibility, highlighting that contractors and subcontractors share waste management responsibilities (Lu and Yuan, 2011). The finding would remind contractors to employ subcontractors with waste management abilities (Ling and Nguyen, 2013). Since contractors are not the only waste producer, other stakeholders, such as subcontractors, should be held accountable for the waste they produce during construction (Lu and Yuan, 2011) and commit to agreed terms and conditions to ensure successful waste management devoid of dispute. The finding is evidence that the willingness of subcontractors to accept some waste management costs will significantly influence waste reduction (Saunders and Wynn 2004). The finding would remind contractors to penalise poor waste management performance (Dainty and Brooke, 2004). For instance, by not shortlisting subcontractors who are not committed to sharing waste management responsibilities.

Identifying recyclable materials supports the philosophy that, since waste cannot be eliminated entirely in construction, there is an opportunity to identify the recyclables to facilitate a closed-loop material flow (He and Yuan, 2020; Liu *et al.,* 2020). Therefore, the findings support the works of numerous researchers that recycling is a good reaction toward waste minimisation by elongating materials' life expectancy (He and Yuan, 2020; Mak *et al.,* 2019). However, the finding contrast with Wahab and Lawal (2011), who found that Nigerian contractors hardly segregate generated waste in projects. Therefore, the finding would remind contractors to understand the economic viability of recyclable materials to recycle more materials in their projects.

Identifying reusable materials and reusing them would help minimise the need for virgin materials and energy for recycling, which has economic and environmental benefits (Ng *et al.,* 2017). This finding agrees with studies advocating for the reuse of materials such as steel bars (Duran *et al.,* 2006), formwork (Ling and Leo, 2000), concrete aggregates (Li, 2008) and others. The finding places a responsibility on contractors to train the employee on materials composition to increase the reuse of construction materials. This would mean that construction materials and components can be reused with little or no alteration to their physical characteristics and without changing their chemical properties.

6. Conclusion

Previous research has shown that waste management is not adequately prioritised in the construction industry. Therefore, this research examined the Nigerian construction actors' waste management priorities regarding materials procurement and construction attributes. Based on the literature review, the research identified four criteria each for managing waste in materials procurement and construction activities. Twenty attributes were identified under the materials procurement criteria, while twenty-two were identified under the construction criteria categories. A team of academic construction experts verified the criteria and attributes. Two hundred and eleven construction practitioners participated in a survey exercise to evaluate the importance of the attributes.

Further, the VAHP method was used to establish the priority weights of the attributes. Then the attributes were categorised into high, medium and low priorities using an equal-interval scale. The research, therefore, presents the main findings from an empirical survey on the critical attributes that can be implemented to improve the effectiveness of materials procurement and construction waste management in Nigeria.

Alliance with suppliers, a take-back clause in suppliers' agreement document, accurate material quantification, accurate material ordering, and just-in-time delivery (JIT) plan are high-priority waste management attributes among the twenty related to materials procurement. The above findings have implications for practice. Their commonalities indicate a need for effective materials and supply chain management to help contractors minimise waste in projects. For instance, rather than concentrating on onsite activities to manage the flow of materials, they suggest cooperation between contractors and suppliers to improve waste management offsite and onsite. This ensures that only the required materials for a job are supplied. However, if excess or the wrong materials are delivered onsite, there would be an opportunity to return them to the supplier.

Further, the senior manager's early commitment to waste minimisation, effective communication among project participants, making subcontractors responsible for their waste, identifying recyclable materials and identifying reusable materials were high priorities for practitioners in the construction stage. The practical implication of these findings reflects the key aspects of good waste management in the construction stage. They show a need to integrate ''soft'' and ''hard'' measures for effective waste management in construction. The findings show that construction companies can adopt soft and hard managerial instruments to address waste management issues from social and technical perspectives. These include communication, legal/mutual agreements with subcontractors, supervision, and increasing recycling and reusing materials to minimise waste disposal to landfills. The findings of this study will be useful for managing waste in the materials procurement and construction stages; therefore, efforts should be made to conduct similar research to improve waste management in the design and end-of-life stages. Hence, the findings may be peculiar to contractors with less or no influence on projects' design and end-of-life stages.

6.1. Recommendations

- ✓ Stakeholders should consider waste management as a critical priority for sustainable development.
- ✓ Contractors should develop and consistently improve partnerships with subcontractors and suppliers at the company level to achieve waste management goals at the project level.
- ✓ Subcontractors should comply with contractors' requirements for waste reduction. For instance, subcontractors should forecast the likely waste streams and identify options for reduction if a contractor requests.
- ✓ Suppliers should be committed and consider themselves as part of the waste management team throughout project implementation (e.g. reduce the quantity of excess packaging, agree with contractors' take-back scheme)
- ✓ There is a need for early supplier involvement in the design process

Future work includes developing frameworks for managing materials procurement and construction waste for Nigerian contractors using the Multi-criteria decision-making (MCDM) concept. The frameworks are designed based on the current research results to assist contractors in identifying and incorporating critical criteria for improving waste management practices in the industry and plan for implementation based on the attributes’ priorities identified in this study.

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