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An Evaluation on the Application of Sustainable Waste Management Principles on Construction Sites in Jimeta-Yola, Nigeria

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Abstract: ***Construction plays a crucial role in developing a country's infrastructure, yet the industry faces significant challenges in managing construction material waste, predominantly generated from the demolition of structures. This waste impacts project costs, profitability, and the environment. Common waste materials include concrete, sand, aggregates, steel, bricks, glass, electrical fixtures, and tiles, with less common materials like paints, PVC pipes, and glass fixtures also affecting profitability. Effective waste management, emphasising the "3R" principles—reduce, reuse, and recycle—is crucial for reducing environmental impact and improving economic outcomes. The study examines the current waste management practices in Yola, Nigeria, identifies challenges, and provides actionable recommendations for enhancing sustainability in construction projects. The research highlights the necessity of sustainable waste management in the rapidly urbanising city of Yola, Nigeria, where construction activities generate substantial waste. The study employs a survey design to gather data on waste management practices from construction professionals in the Jimeta-Yola metropolis. It reveals that broken raw materials like tiles and ceramics, along with structural waste, are the most common types of waste. Recycling and incineration are identified as common waste management strategies, while source reduction and reuse are less practiced. The main causes of waste include inadequate material control and poor storage, leading to damage during transportation and on-site handling. To minimize waste, construction professionals should adopt standard-sized, high-quality materials, secure storage, and proper quality control. The study underscores the need for a shift towards waste prevention strategies to promote a more sustainable and cost-effective construction industry.***

Keywords: Sustainable, Waste, Management

1. Introduction

Construction plays an essential role in developing a country's infrastructure. However, the industry faces a significant challenge in managing construction material waste. This waste is primarily generated from the demolition of structures, with the Environmental Protection Agency (EPA) noting that 90% of total waste in the United States comes from demolition activities, while construction accounts for less than 10% (EPA, OLEM 2016). Construction material waste negatively impacts project costs, profitability, and the environment (Shen et al., 2022). Common waste materials include concrete, sand, aggregates, steel, bricks, glass, electrical fixtures, and tiles, with less common but still significant materials like paints, PVC pipes, and glass electrical fixtures affecting profitability (Hezri, 2018). Managing construction waste is crucial due to its potential for reuse or recycling. Effective waste management can control disposal costs and reduce landfill use. It's estimated that 80% of a homebuilder's waste stream is recyclable, highlighting the importance of source separation and recycling (Tafesse, Girma, Dessalegn, 2022). Additionally, adopting waste management methods can reduce job site liability and increase profitability (Omrani, Naghavi, 2016).

Countries worldwide, including Nigeria, are recognising the need for stringent waste management due to the high volume of waste generated from rapid development (Schall, 2021). The "3R" concept—reduce, reuse, and recycle—has been proposed and implemented to manage waste effectively in construction projects, promoting sustainability (Serpell, 2018). In conclusion, construction waste management through the 3R principles is essential for reducing environmental impact and improving economic outcomes in the construction industry. Effective implementation of these practices can lead to significant benefits, including cost savings and enhanced sustainability. The construction industry is a critical driver of economic development, contributing significantly to infrastructure development and urbanisation. However, it also generates substantial waste, which poses environmental and economic challenges. In Nigeria, particularly in rapidly growing urban areas like Yola, the issue of construction waste management has become increasingly pressing. Construction activities in Yola, as in many parts of Nigeria, result in significant quantities of waste, including concrete, bricks, metals, glass, plastics, and wood. This waste arises from various sources, such as building demolition, renovation activities, and surplus materials from construction sites. The management of this waste is crucial not only for environmental sustainability but also for the economic efficiency of construction projects. The concept of sustainable waste management has gained attention globally, focusing on the principles of reducing, reusing, and recycling waste materials. These principles, often referred to as the "3R" concept, are essential for minimising the environmental footprint of construction activities and optimising resource use. The implementation of these principles in construction practices can lead to reduced waste disposal costs, conservation of natural resources, and improved site efficiency. In Nigeria, the construction industry has traditionally lagged in adopting sustainable waste management practices. The challenges include a lack of regulatory frameworks, limited awareness and training on sustainable practices, and inadequate infrastructure for waste recycling and disposal. However, there is growing recognition of the need for sustainable waste management as part of broader efforts to promote environmental sustainability and economic resilience. Yola, as a rapidly urbanising city, presents a unique context for evaluating the application of sustainable waste management principles. The city's construction boom has led to increased waste generation, putting pressure on existing waste management systems. Evaluating the current practices and identifying gaps can provide valuable insights into how sustainable waste management can be effectively integrated into construction activities in Yola.

2. Research Purpose

The purpose of this research was to evaluate the application of sustainable waste management principles on construction sites in Yola, Nigeria. The research assessed the current waste management practices on these sites to determine their adherence to sustainable principles. It identified the challenges and barriers to effective implementation and provided actionable recommendations for improving waste management practices, promoting sustainability in construction projects. Ultimately, this research will contribute to the body of knowledge on sustainable construction practices, offering insights applicable to similar contexts in Nigeria and other developing countries. This work highlighted the importance of sustainable construction waste management in Nigeria through the 3R principle—Reduce, Reuse, and Recycle. It emphasized reducing waste first, then reusing materials to keep them out of landfills, and finally recycling to create new products. Reusing materials not only benefits the environment by reducing pollution and conserving resources but also supports community well-being and provides affordable access to needed items. The study serves as a benchmark for future projects and students in the field of sustainable construction.

3. Waste Management Strategies on Construction Site

Construction waste management is becoming a pressing problem worldwide. The management of construction waste is no longer just the responsibility of the municipal or the government authorities but that of the developer of the particular land area (Faniran & Caban, 2018). The various ways to manage waste are:

3.1 Source Reduction

Source reduction means minimising the amount and toxicity of solid waste that is generated and subsequently must be disposed of. Resource reduction, often referred to as the "Reduce" principle in the 3Rs (Reduce, Reuse, Recycle), sits at the heart of sustainable practices. It's about minimising the number of resources we use in the first place. Construction and demolition debris can be reduced using the following strategies (Cheung, et al, 2023). Promotion, education and technical assistance. Planning requirements. Reporting requirement. Diversion requirement. Deconstruction requirement Pre-processing requirement (i.e., processing all C&D before landfilling). Resource reduction is the foundation for a sustainable future. By adopting resource-efficient practices in construction and our daily lives, we can conserve valuable resources for future generations, minimize environmental impact, and build a more responsible and sustainable world.

3.2 Reuse

Reuse of materials is an important form of pollution prevention. These changes reduce the amount of waste generated per year. The method is usually adopted in well developed countries. Reusing materials reduces the demand for virgin resources, minimising environmental damage caused by extraction processes. This translates to lower energy consumption during manufacturing, which in turn minimizes air and water pollution associated with new material production. Furthermore, by diverting waste from landfills, reuse reduces landfill overflow and methane emissions. Reusing on-site materials cuts costs by eliminating the need to purchase new ones. Additionally, it supports local businesses involved in collecting, processing, and reselling used materials, contributing to the local economy. Reusing construction waste is no longer a niche practice; it's a strategic approach that benefits the environment, construction budgets, and communities. By overcoming challenges and promoting reuse through collaboration and innovative solutions, the construction industry can move towards a more sustainable future.

3.3 Recycling

According to Skoyles and Skoyles (2017) recycling involves separating reusable materials such as metals, glass and paper from solid waste. The recyclable materials are then processed and returned to the economy as part of other products. Recycling could be on-site; where the contractor reuses waste materials or reprocesses them with the use of machines or job-site; where the contractor only separates the waste materials at the construction site and transports it to the recycling venue. Recycling offers many benefits including, reduced environmental impacts, improvement in the cost effectiveness of waste handling and disposal by providing income from recycled materials and products and finally conservation of natural resources and energy savings in production of new material. Construction waste recycling is limited to a number of waste materials although there are many recycling schemes. To consider recycling materials properties are the major areas to be taken into account (Molete et al, 2013). Thus, a variety of systems and different types of equipment are used and they include: Coarse screen to remove oversized dirt. Magnetic separation to remove ferrous materials and Float tank.

3.4 Incineration

In the incineration process, wastes are burned at very high temperatures and by-products are released into the atmosphere and concentrated into incineration ash. The by-products which are released into the atmosphere contain dust, acidic gases, vaporized metals and toxic chemical such as dioxin which have been linked to public health hazard and environmental degradation. Incineration is therefore not a modern-day best practice for waste disposal.

3.5 Landfills/Dumps

Section Landfilling is the main method of disposal of municipal solid wastes in most countries. Landfilling is not capital intensive and does not require skilled labourers unlike incineration. However gaseous emissions from landfills have been known to contribute to pollution landfills have also been associated with contamination of ground water resource around them. A dump is similar to a landfill except that it is not a systematic waste disposal method, as such no special space, valley or land is provided for the deposition of waste under this approach as with landfills. The waste is deposited more indiscriminately so it is worse than land fill in terms of its contribution to environmental hazard.

4. Causes of Waste on Construction site

There are various causes waste on construction site in Nigeria especially in yola, Adamawa State. These include but limited to the following:

4.1 Material-Related Causes

One of the major causes of waste on construction site is ordering more materials than needed due to inaccurate estimates or fear of running short (Ekanayake & Ofori, 2000). Additionally, Poor quality materials in terms of use of substandard materials that are prone to damage or rejection contributes to waste onsite (Osmani, Glass, & Price, 2008). Hence, according to Nagapan et al. (2012) Improper handling of materials due to damage during transportation, unloading, and storage due to poor handling practices also contributes to wastage onsite.

4.2 Operational Causes

(Ekanayake and Ofori (2000) stated that last-minute changes to design specifications necessitating rework and disposal of old materials contributes to waste. Hence, Inefficient site management leading to cluttered workspaces, making it difficult to track and store materials properly (Kulatunga et al., 2006). Furthermore, Poor storage conditions causing materials to degrade, especially those sensitive to weather conditions (Osmani et al., 2008).

4.3 Human Causes

Mistakes in cutting, measuring, or installing materials, leading to waste from off-cuts and rework (Nagapan et al., 2012). Untrained or poorly trained workers more likely to make errors that result in wasted materials (Kulatunga et al., 2006). Furthermore, Ekanayake and Ofori (2000) opined that miscommunication among project stakeholders (e.g., designers, contractors, and workers) leading to mistakes and rework is one of the human-caused waste on construction site.

4.4 Environmental Causes

Environmentally, adverse weather conditions such as rain, wind, and humidity causing material damage (Osmani et al., 2008). Unexpected events like floods or storms can destroy materials and structures under construction (Nagapan et al., 2012).

4.5 Administrative Causes

Poor project planning and scheduling causing overlaps, delays, and material wastage (Kulatunga et al., 2006). Osmani et al., (2008) stated that non-compliance with building codes and standards leading to demolition and rework administratively causes waste. Additionally, delays in approval processes that result in prolonged exposure of materials to adverse conditions contributes to waste on construction site (Nagapan et al., 2012).

4.6 Economic Causes

Economically, the use of cheap, low-quality materials to save costs, which often results in higher waste due to frequent replacements and rejections and financial constraints in delays in funding causing materials to remain unused and deteriorate on-site causes wastage (Kulatunga et al., 2006).

4.7 Technological Causes

The use of outdated construction methods and tools that are less efficient leading to generation of more waste and limited use of automated systems for accurate measurements and precision cutting, leading to higher manual error rates contributes to waste on construction site (Nagapan et al., 2012).

4.8 Cultural and Behavioural Causes

Lack of awareness about the benefits of waste reduction and recycling among workers and management is one major cause of waste on construction site according to Ekanayake and Ofori (2000).

5. Strategies for the Adoption of 3Rs

Waste management strategies for the adoption of the 3Rs (Reduce, Reuse, Recycle) emphasize minimising waste generation through efficient resource use, promoting the reuse of materials, and enhancing recycling processes to divert waste from landfills and reduce environmental impact.

5.1 Site Waste Management Plans (SWMP)

Site Waste Management Plan (SWMP) is becoming popular nowadays as a valuable approach for assisting construction stakeholders in anticipating the type of construction and demolition (C&D) waste as well as estimating the quantity to make informed decisions for effective waste management (Lu & Yuan, 2022). A waste management plan is required for all public projects and has demonstrated that reuse and recycling rates can be significantly improved. However, the effectiveness of SWMPs is often limited by site constraints and overhead costs. Most construction sites lack sufficient space to carry out on-site sorting, which is labor-intensive, and the enforcement of SWMPs is not common in private projects (Lu & Yuan, 2022). It is necessary to provide more sorting facilities and explore ways to reduce overhead costs to enhance the effectiveness of SWMPs.

5.2 Proper Design

Appropriate design can avoid waste generation at the very beginning stage of construction works, which includes dimensional coordination and standardisation, minimizing the use of temporary works, design for use of recycled materials, avoiding late design modifications, applying low-waste building technologies, backfilling cut and fill by the excavated soils, modeling design information, and other methods (Zhang et al., 2020). Zhang et al. (2020) and Baldwin et al. (2014) suggested that modeling design information flows could evaluate optimized design solutions. However, the lack of mandatory requirements in the green building assessment tool means that designing out waste is not widely practiced in the construction industry (Poon, 2014). Future research on how to properly design out waste is necessary to promote more sustainable practices.

5.3 Deconstruction

Deconstruction, also known as selective demolition, can effectively facilitate the reuse and recycling of construction waste (Energy Rev., 2019). Deconstruction is carried out by reversing the construction processes, requiring planned sorting of the demolished material according to their categories to prevent contaminating recyclable materials such as wood, paper, cardboard, plastic, metal, and concrete aggregates (Manag. Res., 2017). However, expensive manual sorting and insufficient recycling outlets deter contractors from carrying out deconstruction. Additionally, the recycling market in Hong Kong is underdeveloped. A mature recycling market is essential to provide more outlets for recyclable items.

5.4 Prefabrication and Modular Construction

Prefabrication can reduce approximately 52% of construction waste by minimising on-site wet trades and improving buildability. It performs better than conventional construction methods in environmental, economic, and social aspects (Tam & Tam, 2016). The Hong Kong Housing Authority has been a pioneer in using prefabrication for building housing estates. However, the implementation of prefabrication is not common in the private sector, indicating room for improvement. Additionally, prefabrication has some disadvantages, including less flexibility with plans and manufacturing, as well as limitations on transportation.

5.5 On-Site Waste Sorting

On-site sorting is effective in reducing construction waste and recovering valuable materials for reuse and recycling, thereby reducing disposal costs (Tam & Tam, 2016). However, contractors are often reluctant to implement on-site sorting due to congested site conditions, tight construction schedules, high labor demand, expensive operation costs, and lack of recycling outlets (Lu & Yuan, 2022). Off-site sorting can be a viable alternative to promote reuse and recycling since operating costs can be less expensive than direct disposal at landfills. It is necessary to develop more customized on-site recycling equipment and promote thriving off-site recycling facilities (Bao, Lee, & Lu, 2020). Selecting appropriate locations for off-site construction waste sorting facilities to reduce transportation costs and prevent noise and dust is also an important factor to consider.

6. Methodology

The study employs a survey research design to gather information on construction waste management practices within the Jimeta-Yola metropolis. Surveys are an accessible method for respondents to share their knowledge or perspectives, allowing researchers to understand different populations or groups better. This approach helps identify issues and develop solutions based on the respondents' feedback. The survey design used in this study is quantitative, relying on structured, closed-ended questions to collect numerical data that can be analysed statistically to identify trends and patterns within the population. The study is conducted in the Yola metropolis, covering Yola North and South

Local Government Areas in Adamawa State, Nigeria. The area is geographically located between latitude N9°14'-N9°18' and longitude E12°2'-E12°29' and has a population of 1,200,970 as of 2015. The target population for the study includes builders, architects, civil engineers, contractors, technicians, labourers, and clients working in construction firms within the metropolis. Stratified and simple random sampling techniques are used to ensure a representative sample, with the population divided into subgroups based on local government areas and types of companies (public and private), from which 50% of the relevant technical staff are randomly selected.

Data collection is carried out using a researcher-developed questionnaire, divided into two sections: respondent profiles and construction waste control management practices. The questionnaire employs a five-point Likert scale to gauge responses. The method used to analyse the data will be simple statistical tools, specifically the mean and standard deviation. The mean is considered the best representative measure of central tendency. The mathematical processes ensure that the determined priorities for all alternatives are mutually independent. Single value decision scores can be computed using SD 3.0 software for all waste management alternatives to show how these alternatives meet the decision goal (sustainability).

The formulas for finding the values are:

$$\text{Mean}(x) = \frac{\sum X}{N} \quad \text{or} \quad \frac{\sum FX}{N}$$

Where: $\sum \mathrm{FX} =$

Total some of frequency distribution

N = number of samples

And standard deviation of the obtained sample is calculated using the formula below;

Standard deviation (SD)

$$\sigma = \sqrt{\frac{\sum (X - X)^2}{N - 1}}$$

The internal scale of 5.00 with an upper boundary of the mean scale of 3.00. This scale was chosen because 3.00 is the mean, which falls as moderately. An internal scale of 0.05 was added, slightly above the mean level. Thus, the mean is associated with any response equal to or more than 3.05. Responses with a mean score of less than 3.05 are regarded as "disagreed."".

Mean level of acceptance is 3.00 which has been determined, thus:

$$= \frac{5+4+3+2+1}{5}$$

$$= \frac{15}{5}$$

= 3.00

7. Results and Discussion

This study was set out to evaluate the application of sustainable waste management principles on construction sites in Jimrta-Yola, Nigeria, through the application of (Reduction, Re-use and recycling) 3R in the construction sites.

Table 7.1: Mean Responses on the Common Types of Waste on the Construction Sites in Jimeta-Yola.

S/N	Items	$\check{x}$	SD	Remark
1.	structural waste	4.95	0.26	Agreed
2.	finishing waste	2.21	0.22	Disagreed
3.	surplus cement mortar	2.19	0.24	Disagreed
4.	Broken materials	3.96	0.26	Agreed
5.	concrete waste	2.23	0.24	Disagreed
6.	Insulations and asbestos materials	3.21	0.20	Moderately
7.	Metallic waste	3.42	0.22	Agreed
8.	Organic waste			
	$\check{x}$≥300	Mean	grade	=3.96

The data on the types of wastes on construction sites in Jimeta-Yola, Nigeria, as shown on figure 7.1 reveals that broken raw materials, such as tiles and ceramics, are the most prevalent, with a mean of 3.96 and a standard deviation of 0.26. Structural waste is also significant, having a mean of 3.93 and a standard deviation of 0.26. Metallic waste, including pipes, is moderate with a mean of 3.42 and a standard deviation of 0.22. Conversely, surplus cement mortar and concrete fragments are the least common, with means of 2.19 and 2.23, respectively.

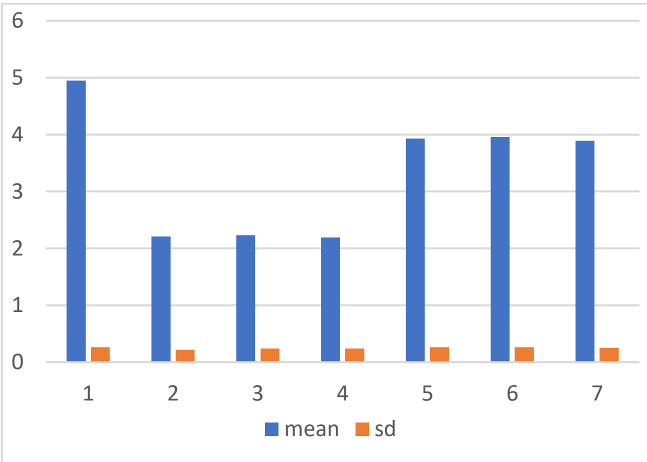

Figure 7.1: Mean Responses on the Common Types of Waste on the Construction Sites in Jimeta-Yola.
Source: Researcher (2024)

Figure 7.1 above shows that the data presented an analysed makes it safe to conclude that broken raw materials like tiles and ceramics and structural waste are the most common types of waste on building construction site in Jimeta-Yola metropolis.

Table 7.2: Mean Responses on the Common Waste Management Strategies Adopted by Professionals Construction Sites in Jimeta-Yola.

S/N	Items	$\breve{x}$	SD	Remark
1.	Source reduction	2.23	0.24	Disagreed
2.	Reuse of waste	2.19	0.24	Disagreed
3.	Recycling of waste	3.93	0.26	Agreed
4.	Incineration	3.96	0.26	Agreed
5.	Landfill	2.21	0.24	Disagreed
6.	Onsite recycling	2.15	0.24	Disagreed
7.	Money (monetising)			
	$\breve{x} \geq 300$	Mean	grade	= 2.78

Table 7.2 shows the common construction waste management strategies adopted by the construction industry in Jimeta-Yola metropolis with different means and standard deviations for each strategy analysed. The respondents disagreed that source reduction is a common construction waste management strategy, as indicated by a mean of 2.23 and a standard deviation of 0.24. In contrast, the respondents agreed that recycling waste materials and incineration are common strategies, with means of 3.93 and 3.96, and standard deviations of 0.26 and 0.26, respectively.

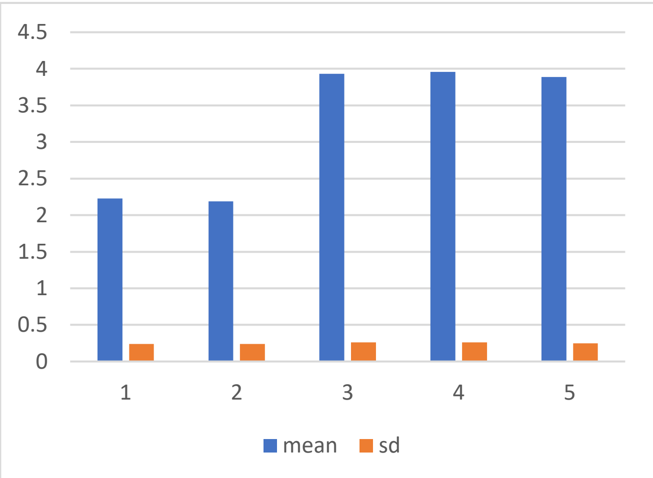

Figure 7.2: Mean Responses on the Common Construction Waste Management Strategies Adopted by Professionals on Construction Sites in Yola.

As shown on figure 7.2 the research exposed that Recycling of waste materials and Incineration are the common construction waste management strategies that are adopted by construction industry professionals whiles Source reduction, Reuse of waste materials, Onsite recycling and Landfill are not commonly used in construction sites domiciled in Jimeta-Yola, Nigeria.

Table 7.3: Mean Responses by Professionals and Clients on the Causes of Waste on Construction Sites in Jimeta-Yola, Nigeria.

S/N	Items	$\breve{x}$	SD	Remark
1.	Inaccurate estimation	2.23	0.24	Disagreed
2.	Workers' mistakes	2.19	0.24	Disagreed
3.	Double handling of materials	3.93	0.26	Agreed
4.	Inadequate control of materials	3.96	0.26	Agreed
5.	Nature of transportation and procurement	3.89	0.25	Agreed
6.	Nature and location of storage	4.05	0.27	Agreed
7.	Professional's site management skills	3.23	0.21	Agreed
	$\bar{x}$≤3.00	Mean	Grade	=3.83

The respondent here includes architects, builders, engineers, contractors, and clients. The findings presented in Table 7.3 revealed that 3.96 and 3.89 mean and standard deviation of 0.26 and 0.25 of the respondents agreed that Inadequate control on construction materials on site and material storage away from the works site and wasted during transportation are the common Causes of Construction Waste on construction site. While only 2.23 mean of 0.24 of standard deviation disagreed that Leftover materials on site.

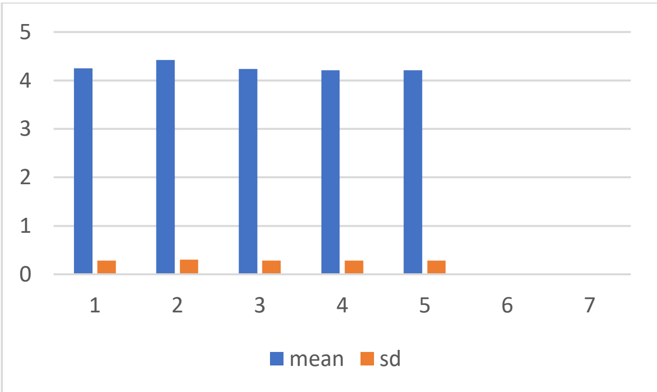

Figure 7.3: Mean Responses by Professionals and Clients on the Causes of Waste on Construction Sites in Jimeta-Yola, Nigeria.

Figure 7.3 revealed base on the data presented and analysed that the Causes of Construction Waste on construction sites in Jimeta-Yola are Poor and wrong storages of materials which has the higher levels and mean.

Table 7.4: Mean Response by Professionals and Clients on Ways of Minimising Waste on Construction Site in Jimeta-Yola

S/N	Items	$\bar{x}$	SD	Remark
1.	Use of standard size and quality materials	4.25	0.28	Agreed
2.	Ensure storage area safe, secure and weather proof	4.42	0.30	Agreed
3.	Minimize reworks from error and poor workmanship	4.24	0.28	Agreed
4.	Coordinate tread or leftover materials, they can be used	4.21	0.28	Agreed
5.	Don't accept poor quality or damages deliveries	4.21	0.28	Agreed
	$\bar{x}$≥3.00	Mean	grade	= 3.91

Table 7.4 shows that all the seven possible strategies that can enhance the adoption of waste management principles on construction site in Jimeta-Yola but at different levels the data shows that 4.42 and 4.25 mean and standard deviation of 0.30 and 0.28 of the respondents agreed with the Recycle (such as broken blocks, plastics, roofing sheets, wood) and Development of Site Waste Management Plans. And also reduce packaging of materials with the mean of 4.24 and standard deviation of 0.28 agreed. And only 2.96 mean and 0.22 standard deviation disagreed that Qualitative estimation of the exact number of materials to be used (only order what is needed).

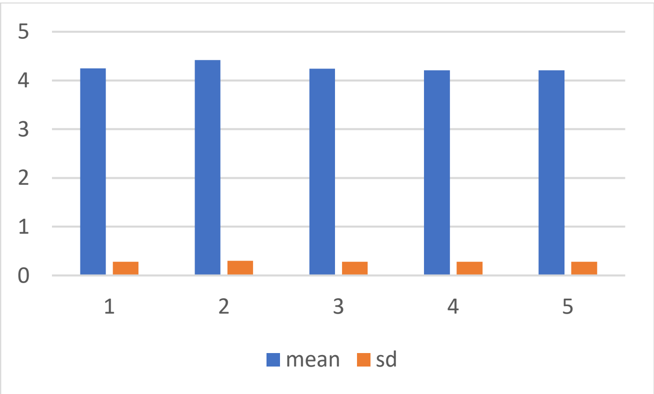

Figure 7.4: Mean Response by Professionals and Clients on Ways of Minimising Waste on Construction Site in Jimeta-Yola

Figure 7.4 revealed on the data presented and analysed that Adopting the use of the right equipment and material for the job and reducing waste disposal on construction site are the possible strategies that can enhance the adoption of waste management principles on construction site in Jimet-Yola, Nigeria.

8. Conclusion

A study on construction waste management in Jimeta-Yola, Nigeria, investigated how effectively the industry applies the "Reduce, Reuse, Recycle" (3R) principles. Broken materials and structural waste topped the list, indicating a need for better material handling. Recycling and incineration were common practices, but there's room for improvement in source reduction, reuse, and on-site recycling. The main culprits for waste generation were poor material control and storage, leading to damage during transport and on-site handling. To minimize waste, construction professionals should focus on using standard-sized, high-quality materials, secure storage, and proper quality control. Additionally, minimising rework, reusing leftover materials, and rejecting poor deliveries can significantly reduce construction waste in Jimeta-Yola. Overall, the study highlights the need for a shift towards waste prevention strategies to promote a more sustainable and cost-effective construction industry.

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