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Construction Waste Reduction in Yola using Circular Economy Approach

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ABSTRACT

The rapid growth in construction activities in Nigeria generates substantial waste, posing significant environmental challenges. The 5R framework (Refuse, Reduce, Reuse, Repurpose, and Recycle) is a pivotal circular economy strategy for mitigating this issue. This study assesses the composition of construction waste, identifies causative factors, and evaluates the adoption of the 5R concept by construction firms in Yola, Nigeria. A quantitative approach was employed utilizing a structured questionnaire survey administered to 50 construction professionals. Data analysis using descriptive statistics and the Relative Importance Index (RII) revealed a significant gap between awareness and practice; while 60% of respondents were aware of the 5R principle, only 39% implemented it. Tile and wood were identified as the most prevalent waste materials. The primary causes of waste were design modifications, inability to reuse materials, and errors in material specifications. The findings indicate that chronic issues like design changes and inadequate planning persist despite known solutions, indicating that the barriers are rooted in economic, cultural, and regulatory domains rather than a lack of knowledge. The study concludes that overcoming the implementation gap requires a multi-faceted approach, including targeted policy interventions such as enforced waste management plans and landfill taxes, economic incentives demonstrating cost savings, and practical on-site training for workers. Translating 5R awareness into effective jobsite practice is essential for sustainable construction waste management in Yola and other areas with similar waste management challenges.

1. Introduction

Solid waste is defined as unwanted and discarded material and contributes significantly to environmental problems, including global warming. The growing population and the rapid expansion of the construction industry that accompany urbanization in each country increase solid waste production [1, 2]. Essentially, how people live and the economic circumstances they are in have impacts on the production of solid waste [3,4]. Likewise, the exponential expansion of construction activities exacerbates the global issue of construction waste [5, 6], which poses significant environmental concerns as it occupies valuable landfill space [7, 8] and can pose a threat to human health and hygiene [9].

Nigeria, much like other developing nations, is grappling with the issue of considerable construction waste production as a result of rapidly expanding population and building and construction industries. A significant portion of recyclable materials in Nigeria end up in landfills [10, 11], and waste management practices in the construction industry remain limited and non-mandatory [12]. This has led to persistent problems of haphazard illegal dumping. Many contractors in Nigeria lack a commitment to source separation, reduction, reuse, or

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recycling at construction sites [13], and the practice of reusing and recycling construction waste has long been overlooked by authorities [14], as it is commonly understood that contractors bear the responsibility of handling construction waste on-site.

In Nigeria, public neglect of local waste reduction concepts originated from the idea that it is the liability of the government to handle the waste cycle. However, behavioural shift has occurred, with individuals increasingly engaging in waste recycling due to its economic viability; the sale of recyclable materials to local industries has become a financial incentive [15]. Furthermore, driven by the global emphasis on sustainable development, there has been a shift towards implementing more comprehensive waste management strategies based on the 5Rs (Refuse, Reduce, Reuse, Repurpose, and Recycle) [16, 17]. The Nigerian government, in its national policy on solid waste management, promotes the 5R framework. This hierarchy prioritizes the most to least environmentally desirable actions. Construction waste is one of the common solid wastes that call for 5R adoption. Figure 1 illustrates the waste management hierarchy based on the 5R framework.

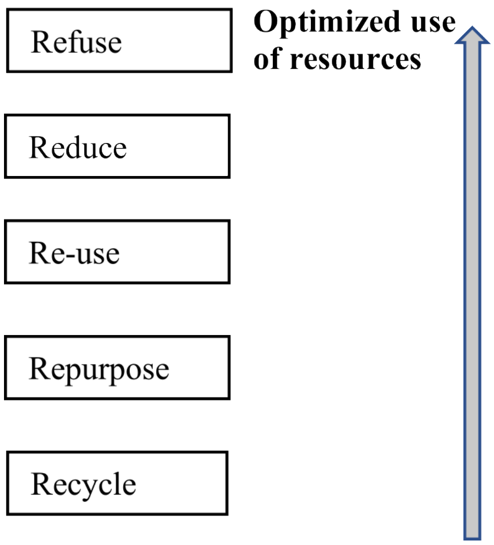

Figure 1. Waste management hierarchy

The 5R hierarchy represents:

I. **Refuse:** This is the most effective strategy, focused on design and procurement. Waste is eliminated before it arrives on-site. It involves processes like specifying standard sized materials to minimise cutting waste, and refusing single use packaging in favour of biodegradable or reusable items such as paper. The use of modern methods like prefabrication can also reduce on-site waste.

II. **Reduce:** Initiatives aimed at reducing waste involve purposeful actions aimed at achieving a substantial decrease in the amount of waste produced and generated, as well as a reduction in its volume, weight, and toxicity prior to processing and disposal.

III. **Reuse:** This entails identifying waste that can be salvaged for re-use on the current project or another project, or that can be donated. Before considering re-use, it may be prudent to evaluate the value of materials in their current salvage state versus their value as recyclable materials. Certain materials can be reused on-site, while others can be sold or donated to a charitable organisation for use as building materials elsewhere.

IV. **Repurpose:** Entails the use of a material for a new purpose without extensive processing. It is also called Upcycling. It is about creativity and seeing potential where others see waste e.g. the use of crush concrete and bricks as sub-base material for new roads or foundations, turning old wooden beams into furniture, use of glass bottles as decorative elements in non-load-bearing walls, etc.

V. **Recycle:** Once all possible measures have been taken to prevent waste, salvage, and re-use materials, the subsequent course of action involves maximising the recycling of the remaining debris. It entails an industrial process to create new materials. Recycling helps to reduce expenses by minimizing the costs associated with waste disposal.

In addition to the 5R framework, other systematic approaches to minimize waste generation have been identified. Research highlights the importance of efficient project scheduling and planning, strong stakeholder communication, and the standardization of procedures [18]. The application of lean construction principles, such as Just-in-Time (JIT) delivery and proper procurement practices, can also significantly reduce excess materials and waste on-site [19]. Furthermore, ensuring the availability of skilled labour and effective workforce management is a critical strategy, as poor workmanship is a well-documented cause of rework and material waste [18].

While studies have shown a growing theoretical awareness of sustainable practices in the Nigerian construction sector, there is a documented gap between this awareness and actual implementation on-site [20]. For instance, research by [21] highlights that barriers such as perceived economic disadvantages and a lack of regulatory enforcement hinder the adoption of waste minimization techniques.

Furthermore, the primary causes of waste on Nigerian construction sites have been identified in previous studies to include design modifications, client changes, inadequate contract document, worker errors leading to rework, and improper material storage **[**22**]**. However, the specific contextual factors influencing waste generation and 5R adoption in a growing urban centre like Yola remain under-investigated.

Currently, the research area lacks a complete database on construction waste, and the 5R initiative is not systematically implemented. Therefore, this study aims to assess the implementation of construction waste management at construction sites in Yola. It specifically seeks to:

1 Gauge the level of awareness and practice of the 5R concept among construction professionals.

2 Identify the key causes of construction waste generation.

3 Analyse the gap between awareness and practice, linking the findings to known barriers and contextual factors.

By doing so, this research will provide insights crucial for enhancing the adoption of 5Rs in material waste management practices in Yola and similar contexts.

2. Methodology

2.1 Study Area

The study was conducted in Yola, the administrative capital of Adamawa State, Nigeria. The city is situated at an approximate elevation of 185.9 meters, within latitudes 9°11'N to 9°20'N and longitudes 12°23'E to 12°33'E. Yola experiences a tropical climate, characterized by a wet season from April to October and a dry season from November to March [23]. The topography is predominantly level with minor undulations. With an estimated population of 325,925 [23], the main sources of employment are agriculture and small-scale industries. Rapid population growth has altered land use patterns and significantly increased waste generation, overwhelming existing disposal methods, which primarily consist of open dumps along the Benue River and in densely populated urban areas. This context makes Yola a pertinent case study for investigating construction waste management challenges.

2.2 Research design and data collection

A quantitative research approach was adopted, utilizing a structured questionnaire survey. This method was selected as it is effective for gathering empirical data from a targeted population, allowing for the systematic measurement of practices and perceptions [24, 25]. The questionnaire was designed to align with the research objectives of identifying key waste sources and evaluating the implementation of the 5R concept. To ensure content validity, the questionnaire was developed based on a review of literature on construction waste management [26]. The instrument employed closed-ended questions structured on ordinal scales to facilitate quantitative analysis.

The target population consisted of construction professionals (architects, builders, engineers, town planners, quantity surveyors) involved in senior-level decision-making on projects within Yola metropolis. A purposive sampling technique was employed to ensure respondents possessed relevant knowledge and experience in construction project management, thereby providing credible insights into waste management practices [27]. While the total population of such professionals in Yola is estimated to be approximately 120, a sample size of 50 (comprising architects, builders, engineers, and quantity surveyors) was targeted for this exploratory study. This sample size is consistent with similar methodological approaches in construction management research within specific geographical contexts where access to a large population is constrained [28].

The questionnaire employed predominantly closed-ended questions structured on a five-point Likert scale to facilitate quantitative analysis and enhance reliability [29]. The collected data was analysed using descriptive statistical methods. Percentages were used to summarize demographic data and response distributions. The Relative Importance Index (RII) was calculated for each factor in sections B and C to rank their perceived significance. The RII was computed using the following formula:

$$R_{II} = (\sum W)/(A \times N) \qquad (1)$$

Where:

R_{II}= Relative importance index,

W = Weight given to each factor by the respondents (ranging from 1 to 5),

N = Total number of respondents, and

A = the highest weight (5).

This analytical technique provides a robust measure for prioritizing factors based on the collective perception of the respondents.

An RII value closer to 1.0 indicates very high significance, while a value closer to 0.0 indicates least significance.

3. Results and discussion

3.1 Awareness and Application of the 5R Concept

The survey revealed a significant disconnect between awareness and practice of the 5R concept among construction professionals in Yola. As shown in Figure 2, 60% of respondents reported being familiar with the 5R framework, primarily through higher education, media, and professional workshops. This level of theoretical awareness is encouraging and suggests that academic and professional institutions are successfully disseminating knowledge on sustainable waste management principles, a trend also observed in other developing contexts by [20].

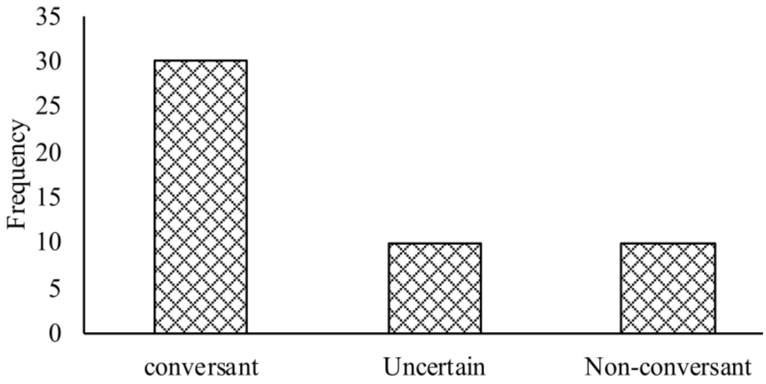

Figure 2. Level of awareness of the 5R concept among respondents

However, this awareness fails to translate into practical application. As depicted in Figure 3, a striking 61% of respondents confirmed that the 5R concept is not used as a waste management strategy on their sites. Instead, the predominant method remains disposal at open dump sites. This finding is critical and aligns with studies such as [20], who identified a similar knowledge-practice gap in the Nigerian construction industry. This can be attributed to a lack of regulatory enforcement, perceived economic disadvantages, and resistance to changing established practices as highlighted by [21].

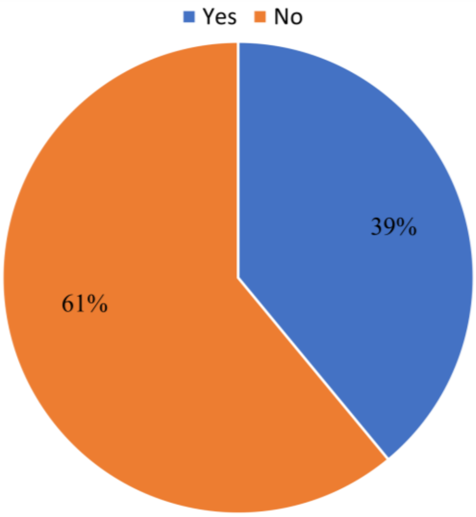

Figure 3. Respondents' usage of the 5R concept

The fact that 20% of respondents were uncertain about the application of the 5R concept further highlights a need for targeted training and advocacy. The reliance on disposal, despite known environmental consequences, suggests that current economic and regulatory structures do not incentivize sustainable practices. For the 5R framework to move from theory to site, stronger policy drivers, client demand for green building, and demonstrated economic benefits of waste minimization are essential.

3.2 Severity of Material Waste and Underlying Causes

Respondents identified tiles, wood, and paint as the most severely wasted materials on construction sites (Figure 4).

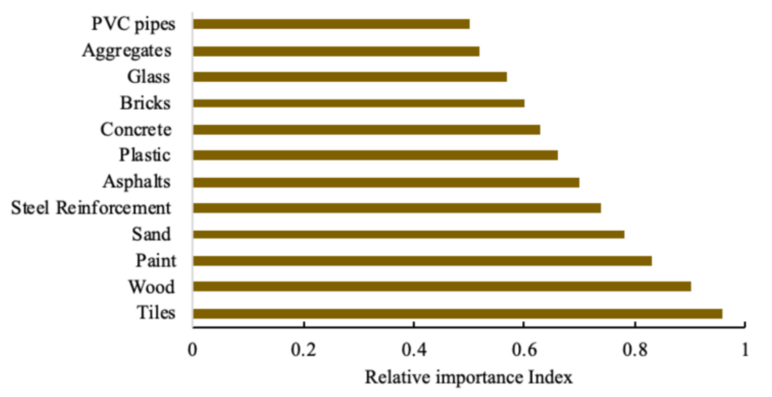

Figure 4. Respondent perception on level of severity of construction waste types on-sites

This is likely a direct consequence of the factors ranked highest in Figure 5, namely, design modifications, inability to reuse materials, and errors in specifications and detailing.

The prevalence of tile waste highlights a failure in the Refuse, Reduce, and Recycle principles. The ranking of design modifications as the primary cause of waste is a well-documented phenomenon [20]. Changes post-procurement render materials obsolete, and changes post-construction generate demolition waste. This emphasizes the paramount importance of the Refuse and Reuse principles at the preconstruction stage. Implementing rigorous design review processes, adopting Building Information Modelling (BIM) for clash detection, and securing full client approval before procurement are crucial steps to mitigate this top cause of waste.

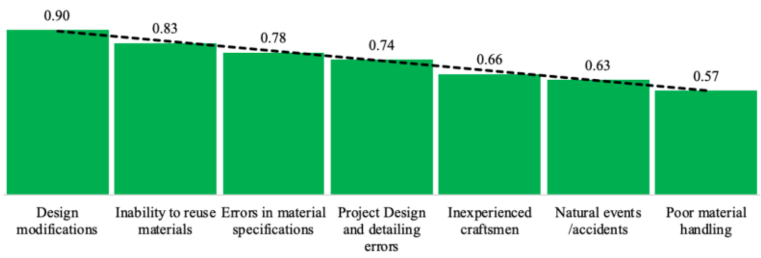

Figure 5. Factors that contribute to waste generation on-site

The high ranking of inability to re-use materials and errors in material specification point to a systematic failure in planning and supply chain management. This directly inhibits the Reuse and Recycle principles. This can be addressed through detailed material planning, establishing partnerships with recycling facilities, and designing for deconstruction (DfD) to ensure materials can be recovered and reused at the end of a building's life.

The significant role of inexperienced craftsmen highlights a human resource dimension to waste generation. Poor workmanship leads to rework, which is a major source of material waste. This finding supports the argument made by [18] that investing in skilled labour and on-site training is not just a cost but a waste reduction strategy that improves overall project quality and efficiency.

3.3 Bridging the Gap Between Awareness and Practice

The core finding of this research is the critical gap between knowing the 5R concept and implementing it. The causes of waste identified are not new or unknown; they are chronic issues well-documented in construction literature globally. The fact that they persist so strongly in Yola, despite awareness of the solution (5R), indicates that the barriers are not technical but are rooted in economic, cultural, and regulatory domains.

To overcome this, a multi-faceted approach is needed:

1. Stronger government policies are needed, such as enforcing waste management plans, levying landfill taxes, and offering incentives for recycling and recovery, as successfully implemented in other developing nations.

2. Demonstrating the cost savings from reduced material purchases and lower disposal fees are crucial to convince contractors. Research into the local economic viability of recycling construction waste is needed to build a compelling business case.

3. Training must move beyond awareness-raising for professionals to include practical, on-site training for craftsmen and foremen on waste sorting, handling, and reduction techniques. Fostering a culture of sustainability within organizations is equally important.

4. Conclusions

The rapid growth of the construction industry has produced a large amount of construction waste and increased the quantity of waste to be disposed of in landfills. Landfills have no capacity to handle the increasing waste over an extended period of time. This paper presents the findings of a survey regarding the implementation of waste minimization strategies by construction companies and the significance of different sources of construction waste. According to the survey findings, a significant number of construction companies lack proper protocols for reducing waste produced at construction sites. In the same way, the implementation of 5R in construction waste reduction among contractors is still in its early stages. A significant majority of contractors fail to implement proper waste management practices in the construction industry. Numerous studies have demonstrated that different forms of construction waste can be refused, reduced, reused, repurposed, or recycled. Therefore, it is important for contractors to fully implement 5Rs construction waste mitigation practices instead of disposing of the waste in landfills or dump sites. It is crucial for all stakeholders to take responsibility and be held accountable for enhancing waste reduction in the construction industry through the 5R approach. Important factors to be emphasised include regulations, the provision of incentives for participating contractors, creating awareness and providing training on the 5R principle, and employing technology. The findings also offer alternative directions for further research into the economic benefits of using the 5Rs waste minimization approach on construction sites for construction industries, construction clients, and the wider community. Findings from these studies would help determine the effective management practices and construction methods needed to prevent, eliminate, or minimize waste at construction sites.

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