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Towards Optimizing Building Material Utilization: Strategies for Mitigating Wastage on Construction Sites in Nigeria

[*1]Aule, T.T, [1]Jide, A.K., [1]Ikharia, I.S., [2]Tijjani, I.N., [2]Saleem, A.F., & [3]Aule, S.I.
[1]Department of Architectural Technology, Federal Polytechnic, Kaura Namoda, Nigeria
[2]Department of Architectural Technology, Federal Polytechnic, Daura, Nigeria
[3]Department of Civil Engineering, Federal Polytechnic, Orogun, Nigeria

[*]**Corresponding author email**: tutee1000@gmail.com

Abstract
The construction industry significantly contributes to economic development but is also a major source of material waste, which escalates costs and harms the environment. This study investigates the factors contributing to material waste on construction sites and explores mitigation strategies. The research adopts a quantitative approach using a cross-sectional survey of construction professionals in Kaduna, Nigeria. A structured questionnaire, utilizing a five-point Likert scale, was administered to a sample of 105 respondents, and data were analysed using descriptive statistics and NVivo 15 for qualitative insights. The findings reveal that design inefficiencies, site mismanagement, poor workforce training, and logistical issues are key contributors to material waste. Design changes during construction (73%), defective site instructions (66%), and complex designs (71%) were identified as major factors. Additionally, poor worker attitudes (65%), inadequate training (65%), and non-standard material sizes (90%) exacerbate waste. Environmental influences, including adverse weather conditions (64%) and site topography (72%), also play significant roles. To minimize waste, respondents emphasized proper material handling, improved design processes, site supervision, and enhanced storage practices. This study highlights the need for integrated waste reduction strategies in construction. However, further research is needed to explore technological interventions such as digital modelling and automation for waste minimization. The findings contribute to advancing sustainable construction practices by promoting resource efficiency and environmental responsibility.

Keywords: Construction Waste Management, Sustainable Building Practices, Material Waste Reduction, Waste Mitigation Strategies, Site Management Efficiency

Introduction

The construction industry plays a pivotal role in economic growth, but is also a significant contributor to environmental degradation, primarily through material waste generated on construction sites. According to the United Nations Environment Programme (2021), construction and demolition waste constitutes approximately 30% of total global waste. This alarming statistic underscores the urgent need to address material waste, which not only escalates project costs but also depletes natural resources and contributes to environmental pollution. Material waste refers to surplus materials that are discarded or remain unused during construction activities, resulting from issues such as over-ordering, improper handling, and design changes (Ajayi et al., 2017). Key concepts associated with material waste include construction waste management, which focuses on strategies to minimise waste generation and enhance material reuse and recycling (Roy et al., 2023). Additionally, material efficiency highlights the need for optimal resource utilisation to reduce waste without compromising project quality (Chen et al., 2024). The necessity for this research is evident in the persistent challenges that the construction industry faces regarding waste management. Studies indicate that construction waste accounts for 20% to 30% of total material inputs, leading to significant financial losses and environmental impact (Zhao et al., 2021). Furthermore, Aule et al. (2022) noted that the global push for sustainable development, particularly through the United Nations Sustainable Development Goals (SDGs), calls for immediate productive actions by promoting sustainable practices and reducing waste within the built environment industry. This study aims to explore the factors contributing to material waste on construction sites and

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identify effective strategies for its mitigation. By providing insights into the dynamics of material waste, the research will inform construction professionals, policymakers, and stakeholders about best practices in waste management. The findings will contribute to advancing sustainable construction methods, ultimately promoting environmental responsibility and enhancing the economic efficiency of construction projects. Addressing material waste on construction sites is vital for fostering sustainability in the industry. This research aspires to bridge existing knowledge gaps, providing actionable recommendations to reduce material waste and encouraging a transition towards more sustainable construction practices.

Materials and Methods

This research is grounded in quantitative data gathered through a cross-sectional survey targeting construction professionals to identify factors contributing to material waste and potential mitigation strategies. The study employed convenient non-probability sampling within the Kaduna metropolis, engaging a diverse range of professionals, including architects, builders, civil engineers, and quantity surveyors. With an estimated population of 200 construction offices in Kaduna, the Taro Yamane sampling formula was applied, ensuring a sample size of at least 100 respondents, which facilitates reliable content validation (Yamane, 1967). The survey utilised a well-structured questionnaire, administered face-to-face, designed to capture demographic information alongside material waste factors and mitigation strategies. While demographic data required nominal categorisation, the remaining sections employed a five-point Likert scale ranging from "strongly disagree" (1) to "strongly agree" (5), with a neutral option (3) in the centre. Of the distributed questionnaires, 105 were returned fully completed, ensuring the integrity of the data. The quantitative data underwent simple descriptive analysis, primarily using cross-tabulation techniques and a qualitative content analysis was conducted with NVivo 15 software. This methodological approach aligns with best practices in construction research ensuring comprehensive insights into material waste dynamics (Aule et al., 2022; Shastri, et al., 2021).

Results

Biodata of Research Respondents

Table 1 provides a breakdown of the respondents based on their professional affiliation, educational qualification, and years of experience, offering insight into the study's participant composition. Regarding professional affiliation, the majority of respondents were builders (36.2%), followed by quantity surveyors (24.8%), architects (16.2%), and civil engineers (7.6%). This distribution reflects the broad engagement of key players in the construction industry, consistent with studies highlighting the importance of multidisciplinary involvement in construction-related research (Adeyemi, 2023). The inclusion of builders and quantity surveyors is crucial, as they play vital roles in project execution and cost management, aligning with recent findings on their influence on project outcomes (Oke et al., 2022). In terms of educational qualification, most respondents were graduates (37.1%) and undergraduates (31.4%), with a smaller percentage holding postgraduate degrees (12.4% master's and 8.6% doctorate). This reflects a typical education landscape in construction professions, where undergraduate degrees provide the foundational skills necessary for professional practice, while postgraduate degrees enhance specialised knowledge. Studies by Babatunde et al. (2022) suggest that an educational mix ensures a blend of practical and theoretical insights, vital for addressing complex industry challenges.

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Table 1: Biodata of Research Respondents

Category	Variables	Frequency	Percentage (%)	
Professional Affiliation	Architect	17	16.2	100
	Builder	38	36.2	
	Civil Engineer	08	7.6	
	Quantity Surveyor	26	24.8	
	Other	16	15.2	
Educational Qualification	Doctorate	9	8.6	100
	Masters	13	12.4	
	Graduate	39	37.1	
	Undergraduate	33	31.4	
	Others	11	10.5	
Respondents' Experience	1 – 4 years	23	21.9	100
	4 – 9 years	48	45.7	
	Above 10 years	34	32.4	

Source: Survey Responses from Fieldwork

Finally, the respondents' experience shows that 45.7% have 4–9 years of experience, with significant representation from both early-career (21.9%) and highly experienced professionals (32.4%). This spread is ideal for capturing a wide range of perspectives, from innovative approaches to seasoned expertise, a balance supported by industry studies (Bertino et al., 2021). This sample, therefore, ensures comprehensive input from relevant, experienced professionals across various construction disciplines.

Factors for Material Waste

The results in Table 2 highlight several key contributors to material wastage in construction projects, categorized under design and site instruction, site production and management, resource material factors, delivery issues, and environmental influences. Notably, defective site instructions (66%) and design changes during construction (73%) emerged as major sources of material waste. Frequent alterations in design disrupt workflows, necessitating additional material procurement and leading to resource wastage. This aligns with Ogunbiyi et al. (2023), who emphasize that excessive design modifications result in inefficiencies and cost overruns. Similarly, complex designs (71%) were found to exacerbate material wastage, reinforcing findings by Akinradewo et al. (2020), who identified intricate structural elements as a key driver of rework and excessive material use.

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Table 2: Contributors to Material Wastage in Construction Projects

Construct	Variable	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
	Wastage due to defective site instruction	9	18	12	40	26
	Wastage due to change of design during construction	8	13	11	33	40
	Wastage due to poor design	15	20	12	24	34
	Wastage due to complex design	11	16	06	345	39
Design and Site Instruction	Wastage due to inadequate supervision	11	13	17	39	25
	Poor work attitude and management	11	13	16	40	25
	Inadequate training of craftsmen	11	18	11	39	26
	Wastage due to material reworking	15	20	12	24	34
	Wastage due to poor working conditions	11	12	19	38	25
	Wastage due to inexperienced workers	8	13	11	32	41
Site	Wastage due to poor site layout	7	19	10	29	40
Production and Management	Change of contractor Midway	40	28	15	14	8
	Wastage due to excessive quantity usage	10	19	7	29	40
	Wastage due to inferior materials usage	11	16	6	34	38
	Wastage due to poor storage	7	19	10	29	41
	Wastage due to misuse of materials	20	15	12	23	35
Resources Material Factors	Wastage due to improper handling of materials	11	13	16	34	38
	Delivery of low-quality materials	9	11	15	33	37
	Poor transportation network	6	19	10	29	41
	Delivery of non-standard material sizes	5	6	4	37	53
Delivery	Delivery of improperly specified materials	14	8	14	41	28
Factors of Material Waste	Improper packaging of materials	15	20	12	24	34
	Material deterioration due to weather and climate	10	19	12	26	38
	Damage by insects and pests	17	13	11	25	39
	Damage due to natural calamities	15	20	12	25	33
Environmental Factors of Material Waste	Damage due to site profile and topography	8	13	11	32	40

Source: Survey Responses from Fieldwork

In the domain of site production and management, poor work attitudes (65%) and inadequate training of craftsmen (65%) were significant concerns, reflecting previous studies that link skill deficiencies with high waste levels (Ayodele et al., 2020). Additionally, inexperienced workers (73%) and poor site layout (69%) further contributed to inefficiencies. Research by Oke et al. (2022) supports these findings, indicating that improper workforce management exacerbates material misuse and inefficiencies in resource allocation. Regarding resource material factors, excessive material usage (69%), inferior materials (72%), and poor storage practices (69%) were major concerns. These issues are consistent with Nwaichi et al. (2014), who stress that material preservation strategies such as proper storage and specification standardization are vital in mitigating construction waste. Similarly, improper material handling (72%) was identified as a major contributor, corroborating findings by Oke et al. (2021), who noted that mishandling leads

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to increased breakage and disposal of resources. Delivery factors, including non-standard material sizes (90%) and poor transportation networks (70%), significantly influenced waste generation. These results confirm the assertions of Ogunbiyi et al. (2023), who highlighted logistical inefficiencies as a leading cause of excessive material loss. Environmental factors, including damage from weather conditions (64%), pests (64%), and natural calamities (61%), further compounded waste generation, supporting Nwaichi et al. (2023), who emphasize the importance of preventive treatments and climate-adaptive material selection.

Strategy for Minimising Waste on Construction Sites

Table 3 outlines respondents' views on strategies for minimising waste on construction sites, focusing on material deterioration and site-specific challenges. The data shows strong agreement with the need for strategies addressing "material deterioration due to weather and climate," with 64% of respondents agreeing or strongly agreeing. This underscores the importance of climate-resilient material management, as highlighted by Bello et al. (2024), who argue that proper storage, timely usage, and protective measures (e.g., waterproofing) can minimise weather-induced material damage.

Table 3: Strategies for Minimising Waste on Construction Sites

Variable	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
Effective control of materials from design to construction stages	11	19	11	41	26
Evolving better means and facilities for material storage	15	20	12	24	34
Use of prefabricated elements	11	12	19	38	25
Incorporating a waste management plan	8	13	11	32	41
Enlightenment and training of Site worker	7	19	11	29	40
Reusing or recycling materials	11	16	6	34	9

Source: Survey Responses from Fieldwork

The variable "damage by insects and pests" received 64% agreement, suggesting that pest control strategies are critical in waste reduction. Ogunbiyi et al. (2023) emphasise the need for preventive measures, such as the use of treated wood, proper sealing of materials, and regular site inspections, to mitigate insect and pest damage, which can lead to material waste and project delays. "Damage due to natural calamities" had 58% agreement, reflecting the importance of incorporating disaster risk management into construction planning. Oke et al. (2021) advocate for designing structures and material handling practices that can withstand potential natural disasters, thus minimising post-calamity material wastage. Lastly, "damage due to site profile and topography" garnered the highest agreement (72%). Respondents recognise the importance of assessing and adapting to the physical site conditions. Proper site analysis and material selection based on topography, as supported by Ayodele et al. (2020), can prevent erosion, flooding, and other issues that lead to material wastage. Largely, these findings reinforce existing literature while emphasizing the need for integrated waste mitigation strategies that address multiple interrelated factors. A holistic approach, including improved design efficiency, better workforce training, enhanced storage practices, and optimized logistics, can significantly reduce material wastage and enhance sustainability in the construction sector.

Discussion

The analysis of the tables reveals two key themes: factors contributing to material waste on construction sites and strategies for minimising such waste.

Factors for Material Waste

Material wastage on construction sites is influenced by several factors, such as inefficiencies like defective site instructions (66%) and design changes during construction (73%), as shown in Table 2. These issues disrupt workflow and lead to unnecessary material use, a point reinforced by Akinradewo et al. (2020), who emphasise the need for clear communication and design consistency. The table also identified factors like poor work attitude and management

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(65%) and inadequate training of artisans (65%), both of which hinder efficiency. Ogunbiyi et al. (2023) highlight that training deficiencies and poor oversight contribute significantly to rework and material misuse. Moreover, the table emphasised external influences like improper handling of materials (72%) and excessive material usage (69%), pointing to poor on-site practices as major contributors to waste. Oke, et al. (2021) similarly find that handling materials incorrectly leads to high wastage levels, calling for better storage and usage protocols. Furthermore, the table adds logistical challenges such as the delivery of non-standard materials (90%) and poor transportation networks (70%), confirming the role of supply chain issues in exacerbating material wastage. Ayodele et al. (2020) argue that inefficiencies in material procurement and logistics can significantly affect project timelines and resource use.

Strategies for Minimising Material Waste

Effective strategies to minimise material waste are evident in Table 3. The top strategy is adapting to site profiles and topography (72%), a method supported by Ayodele et al. (2020), who emphasise the importance of tailoring construction processes to site-specific conditions to reduce waste. The table further highlights waste management strategies such as recycling materials (58%) and better material storage facilities (70%), both vital to minimising waste. According to Bello et al. (2024), incorporating proper storage and recycling protocols not only reduces material waste but also enhances environmental sustainability.

In brief, the results across the tables provide a comprehensive view of the internal and external factors driving material waste on construction sites. Strategies like improving site management, enhancing worker training, adapting to environmental conditions, and optimising material logistics are supported by current research and offer effective ways to minimise waste and improve efficiency.

Summary

Figure 1 presents a thematic qualitative summary of key factors contributing to material waste in construction, with "material" (94 occurrences) and "wastage" (39) being central. Key waste drivers include poor "design" (65), "management" (26), inadequate "training" (28), and inefficiencies at the "site" (28). Contributing factors like "damage" (15) and "improper" practices (10) also feature prominently.

Figure 1: Thematic Summary of Factors Contributing to Material Waste
Source: Qualitative Textual Exploration Using NVivo 15

Mitigation strategies emphasise "reducing" (12), improving "quality" (8), better "management" (26), and proper "storage" (9). Effective design and execution, along with improved "recycling" (4) and supervision, are critical to minimising material waste and ensuring efficient project outcomes.

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Conclusion

This study highlights the critical issue of material waste in the construction industry, emphasising the multifaceted factors contributing to waste generation and the urgent need for effective mitigation strategies. The findings reveal that inefficiencies such as over-ordering, inadequate planning, and poor site management significantly impact material waste levels on construction sites. By identifying these key contributors, the research provides valuable insights for construction professionals seeking to enhance their waste management practices. Furthermore, the study underscores the importance of adopting sustainable construction methods that prioritise material efficiency and resource optimisation. By implementing strategies such as improved project planning, better procurement practices, and the incorporation of recycling and reuse initiatives, the industry can significantly reduce material waste, thereby minimising its environmental footprint and associated costs. Ultimately, this research contributes to the broader discourse on sustainable construction, offering practical recommendations that align with global sustainability goals. By addressing material waste effectively, the construction industry can not only improve its economic viability but also play a pivotal role in promoting environmental stewardship. Future studies should continue to explore innovative solutions and technologies that can further enhance waste management practices, ensuring a more sustainable future for the construction sector. Through collaborative efforts among stakeholders, it is possible to transition towards a more resource-efficient industry that values sustainability alongside economic growth.

Recommendations

To effectively mitigate material waste on construction sites and promote sustainability, several strategic measures should be implemented.

1. Firstly, enhancing design and planning efficiency is crucial. Utilizing Building Information Modelling (BIM) and other digital tools can help reduce design errors and minimize on-site modifications. Conducting thorough pre-construction planning will prevent design changes and unnecessary material use, while standardizing design practices can simplify construction processes and reduce waste generation.
2. Secondly, strengthening site management and supervision is essential for minimizing material wastage. Implementing stringent site supervision can ensure proper material handling and prevent unnecessary disposal of resources. Adopting lean construction principles can streamline workflows and enhance material efficiency, while establishing a waste tracking system can monitor and reduce material waste at different construction stages.
3. Furthermore, improving workforce training and awareness is necessary to foster responsible construction practices. Organizing regular training sessions for construction workers on best practices for material handling and storage can significantly reduce wastage. Raising awareness about the financial and environmental impacts of material waste among industry professionals will encourage more responsible resource usage. Additionally, enhancing skill development programs for artisans and supervisors will promote efficient resource utilization and reduce avoidable waste.
4. Optimizing material procurement and storage is another critical recommendation. Improving procurement strategies by accurately estimating material requirements and adopting just-in-time delivery methods can minimize surplus materials. Ensuring the use of durable, high-quality materials will reduce waste caused by defects and damages. Moreover, enhancing storage facilities to protect materials from environmental factors, pests, and poor handling will further contribute to reducing construction waste.
5. Lastly, promoting recycling and sustainable practices is vital for a more environmentally responsible construction industry. Encouraging on-site recycling and reuse of materials such as wood, metal, and concrete can significantly decrease waste disposal. Integrating prefabrication techniques will minimize construction waste and improve efficiency, while fostering partnerships with recycling companies can facilitate the proper disposal and repurposing of construction waste.

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