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Towards Enhancing Sustainable Building Projects in Nigeria: Analysing Construction Waste Factors, Challenges, and Mitigation Strategies

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Abstract

Material waste is a persistent challenge in the construction industry, leading to cost overruns, project delays, and environmental degradation. Despite ongoing efforts to minimize waste, inefficiencies related to design, site management, resource handling, delivery, and environmental factors continue to impact construction projects. This study investigates key contributors to material waste using a structured survey and statistical analysis. The findings reveal that defective site instructions (66% agreement), frequent design changes (73%), and complex designs (84%) significantly influence material wastage. Additionally, poor work attitude (65%), inadequate training (65%), and excessive material usage (69%) were identified as major concerns. Environmental conditions, including weather-induced material deterioration (64%) and site topography challenges (72%), further exacerbate waste. The study highlights the significance of proper planning, supervision, and adherence to standard practices in reducing material losses. The findings are valuable for construction professionals, policymakers, and researchers seeking sustainable waste management strategies. However, limitations include the study's reliance on survey data, which may not fully capture contextual variations in waste generation. Future research should explore advanced technologies, such as Building Information Modelling (BIM), and real-time waste tracking systems to enhance construction efficiency and sustainability.

Keywords: *Material waste, Construction management, Design inefficiencies, Environmental factors, Sustainability*

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Background to the Study

Material waste in construction projects remains a significant challenge, affecting cost efficiency, environmental sustainability, and project timelines. The construction industry generates a substantial amount of waste due to factors such as defective site instructions, frequent design changes, poor site management, inefficient material handling, and environmental conditions. According to Akinade and Oyedele (2024, construction waste accounts for a large proportion of global solid waste, contributing to resource depletion and increased project costs. Despite advancements in construction techniques and waste management strategies, inefficiencies in material usage persist, necessitating further investigation into the underlying causes. Addressing this issue is crucial for improving sustainability in construction practices, reducing financial losses, and enhancing overall project efficiency.

The research problem underpinning this study is the persistent material waste in construction projects, which arises from multiple interrelated factors such as poor supervision, inadequate planning, low-quality materials, and improper storage. Previous studies (Akinradewo et al., 2020) have identified these factors; however, a comprehensive assessment linking design issues, site management, procurement challenges, and environmental influences is still lacking. This study aims to fill this gap by systematically analysing various waste-generating factors and evaluating their impact on construction efficiency. The primary research objectives include examining how design and site instruction factors contribute to material waste, assessing the role of site production and management practices, investigating the impact of resource material factors, evaluating delivery-related inefficiencies, and analysing environmental influences on material deterioration.

This study holds significant implications for multiple stakeholders in the construction industry. For construction professionals, including architects, engineers, and project managers, the findings provide insights into best practices for minimizing material waste through effective planning and quality control. Policymakers and regulatory bodies can use the study to formulate policies that promote sustainable construction practices and waste reduction strategies. Additionally, contractors and suppliers can benefit by optimizing material procurement, handling, and storage to reduce losses and improve cost efficiency. Ultimately, reducing material waste enhances sustainability and aligns with global efforts toward sustainable development goals (SDGs), particularly responsible consumption and production Aule et al., (2022a).

Despite its contributions, this study has certain limitations. The research is based on field data, which may reflect region-specific conditions and may not be fully generalizable to all construction environments. Additionally, while the study identifies key waste factors, further investigation is needed to explore the effectiveness of various mitigation strategies in diverse construction settings. Future studies should examine advanced technologies such as digital modelling, automation, and circular economy approaches to enhance material efficiency. By addressing these limitations, future research can build on the findings to develop more effective and globally applicable waste reduction strategies in the construction industry.

Materials and Methods

This study adopts a quantitative research approach to investigate factors contributing to material waste in construction, focusing on five key variables: Design and Site Instruction Factors, Site Production and Management Factors, Resource Material Factors, Delivery Factors, and Environmental Factors. A structured survey was conducted among construction professionals in Kaduna to identify the causes of material waste and effective mitigation strategies. The study employed a convenient non-probability sampling technique due to accessibility constraints and the need to capture the perspectives of professionals such as architects, builders, civil engineers, and quantity surveyors. Based on an estimated 200 construction offices, the Taro Yamane formula (Yamane, 1967) was applied to ensure a minimum sample size of 100 respondents, providing reliable statistical analysis.

The questionnaire, designed for face-to-face administration, included both demographic questions and material waste factors measured using a five-point Likert scale. This scale was chosen for its ability to capture attitudinal variations effectively (Joshi et al., 2015). Design and site instruction factors addressed issues such as unclear drawings and last-minute changes that lead to material waste (Ajayi et al., 2017). Site production and management factors encompass poor scheduling and unskilled labour, which cause inefficiencies (Osmani, 2012). Resource material factors involved overordering and improper handling of materials, increasing waste (Nagapan et al., 2012). Delivery factors examined supply chain inefficiencies, while environmental factors considered weather-related material damage (Tam et al., 2007). According to Aule et al., (2022b), data analysis involved descriptive statistics using cross-tabulation and qualitative content analysis with NVivo 15, ensuring robust insights into waste generation patterns Šompláket al., (2023).

Results

Design and Site Instruction Factors

This section assessed the impact of design and site instruction factors on material waste in construction using a Likert scale to measure respondents' perceptions. The findings in Table 1 indicate that defective site instructions significantly contribute to waste, with 66% of respondents agreeing or strongly agreeing. Defective site instructions refer to unclear, inconsistent, or incorrect directives issued on-site, leading to rework and excess material use. This aligns with Akinradewo et al. (2020), who emphasized that effective communication reduces errors and waste.

Table 1: Design and Site Instruction Factors of Material Waste

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
Wastage due to inadequate supervision	11	13	17	39	25

Source: Fieldwork

Similarly, design changes during construction emerged as a major factor, with 73% agreement. Frequent design modifications disrupt workflow, increase material orders, and generate unnecessary waste. Love et al., (2014) assert that excessive design alterations lead to cost overruns and inefficiencies, supporting this study's findings. However, while design changes are sometimes unavoidable due to unforeseen project needs, proactive planning can mitigate their negative effects.

Poor design was also identified as a waste contributor, with 58% agreement. Poorly conceived designs often result in inaccurate material estimates and construction defects, as noted by Oke, et al., (2021) Compared to design modifications, poor design has a slightly lower agreement level, suggesting that while problematic, it may not be as immediate a concern as on-site changes.

Notably, complex designs received the highest agreement (84%), indicating that intricate architectural plans often lead to material overuse and inefficiencies. Bello, et al., (2024) Bello, et al., (2024) argue that simpler designs enhance material efficiency, a perspective that reinforces these findings. Lastly, inadequate supervision had a 64% agreement rate, signifying its role in waste generation. Ayodele et al., (2020) highlight that proper oversight ensures optimal material use and compliance with project standards. Compared to other factors, inadequate supervision is less impactful than complex designs but remains a critical consideration.

Site Production and Management Factors

This section evaluated site production and management factors contributing to material waste in construction projects. The results presented in Table 2 indicate that poor work attitude and management significantly impact waste generation, with 65% of respondents agreeing or strongly agreeing. Poor work attitude refers to a lack of commitment, carelessness, and disregard for material efficiency, while ineffective management involves inadequate supervision, scheduling, and coordination. Oke, et al., (2021) identified these factors as major contributors to construction inefficiencies, leading to delays and material overuse.

Table 2: Site Production and Management Factors of Material Waste

Variable	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
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
Wastage due to poor site layout	7	19	10	29	40
Change of contractor Midway	40	28	15	14	8

Source: Fieldwork

Similarly, inadequate training of craftsmen received 65% agreement, highlighting the need for continuous skill development among workers. Poorly trained craftsmen are more likely to make errors, leading to rework and waste. Ayodele et al., (2020) stress that training programs enhance workmanship quality and reduce material loss, reinforcing the importance of upskilling initiatives.

Material reworking, a major contributor to waste, received a 58% agreement. Rework occurs due to construction errors, poor craftsmanship, or design modifications, increasing material consumption. Akinradewo et al., (2020) found that excessive rework results from poor project supervision and lack of adherence to design specifications, aligning with this study's findings.

Inexperienced workers were identified as a critical issue, with 73% agreement. Workers lacking industry experience often struggle with efficient material use and construction best practices, leading to higher wastage. Ogunsemi and Aje (2022) emphasize that mentoring inexperienced workers can mitigate this issue. Interestingly, the change of contractor midway had 68% disagreement, suggesting it is not a widespread problem. However, Olatunji et al., (2024) argue that in certain contexts, contractor changes can disrupt workflow and lead to inefficiencies.

Resources Material Factors

This section examined resource-related factors contributing to material waste in construction. The findings, as presented in Table 3 reveal that excessive quantity usage is a significant concern, with 69% of respondents agreeing or strongly agreeing. This issue arises when material estimates exceed actual project requirements, leading to surplus and eventual waste. Bello, et al., (2024) emphasize that poor quantity surveying and procurement planning contribute to this problem, highlighting the importance of precise estimation techniques to minimize excess.

Table 3: Resources Material Factors of Material Waste

Variable	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
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
Wastage due to improper handling of materials	11	13	16	34	38

Source: Fieldwork

The use of inferior materials also received high agreement (72%), indicating that substandard materials contribute to construction waste. Inferior materials often fail to meet project specifications, leading to frequent replacements and increased wastage. Love et al., (2012) argue that material quality control during procurement is essential to prevent unnecessary waste and maintain construction integrity. Compared to excessive quantity usage, inferior materials pose additional risks by affecting project durability and requiring costly corrections. Poor storage practices were identified as another key factor, with 70% agreement. Construction materials are susceptible to damage if improperly stored, particularly in harsh environmental conditions. Ayodele et al., (2020) advocate for efficient storage systems to protect materials from deterioration, reinforcing the need for structured inventory management.

Material misuse garnered moderate agreement (58%), reflecting the impact of improper application and handling. Workers unfamiliar with correct usage methods often waste materials through errors or inefficiencies. Oke et al., (2021) highlight that structured training programs can significantly reduce waste caused by misuse. Finally, improper material handling was another major concern (72%), emphasizing that careless handling can lead to breakage, spillage, or loss. This finding aligns with previous studies suggesting that implementing handling protocols can improve material efficiency (Ayodele et al., 2020).

Delivery Factors of Material Waste

This section investigated the impact of delivery-related issues on material waste in construction projects, as presented in Table 4. Findings reveal that the delivery of low-quality materials significantly contributes to waste, with 70% of respondents agreeing or strongly agreeing. Low-quality materials often fail to meet structural and durability requirements, leading to rework and additional material consumption. Akinradewo et al., (2020) highlight that inadequate quality control in procurement can result in substandard materials that compromise structural integrity, leading to inefficiencies and cost overruns.

Table 4: Delivery Factors of Material Waste

Variable	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
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 of improperly specified materials	14	8	14	41	28
Improper packaging of materials	15	20	12	24	34

Source: Fieldwork

Similarly, poor transportation networks received 70% agreement, indicating that inadequate infrastructure negatively affects material delivery. Efficient transportation systems ensure timely and safe delivery, reducing delays and damage risks. Oke et al., (2021) emphasize that logistical challenges in material supply chains can lead to project slowdowns and increased waste due to material exposure or improper handling.

A particularly critical issue is the delivery of non-standard material sizes, which received the highest agreement rate (90%). Non-standard materials often require modifications on-site, leading to excess cutting and waste. Love et al., (2012) stress that strict adherence to standard specifications can significantly reduce construction waste and improve project efficiency. Compared to other delivery factors, non-standard sizing presents a more immediate and substantial challenge, requiring strict quality assurance at the sourcing stage. In contrast, delivery of improperly specified materials had lower agreement (41%), suggesting that while it does contribute to inefficiencies, it is not as prevalent as other issues. However, Ayodele et al., (2020) argue that even minor specification errors can disrupt project timelines and result in waste. Lastly, improper material packaging (58% agreement) emerged as a moderate concern, as poorly packaged materials are prone to damage during transportation. Bello et al., (2024) advocate for improved packaging standards to minimize loss and enhance material usability.

Environmental Factors of Material Waste

Environmental conditions play a crucial role in material waste in construction projects, as shown in Table 5. The study reveals that material deterioration due to weather and climate is a major concern, with 64% of respondents agreeing or strongly agreeing. Weather elements such as excessive moisture, temperature fluctuations, and prolonged exposure to sunlight degrade construction materials over time. Bello et al., (2024) highlight that poor weather protection measures can reduce material lifespan, leading to increased replacement costs and project inefficiencies. Implementing protective storage solutions can mitigate these risks.

Table 5: Environmental Factors of Material Waste

Variable	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
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
Damage due to site profile and topography	8	13	11	32	40

Source: Fieldwork

Similarly, damage by insects and pests received 64% agreement, indicating a significant challenge in material preservation. Organic materials such as wood are particularly vulnerable to termite infestations and fungal decay, which can weaken structural integrity. Nwaichi et al., (2023) emphasize that preventive treatments, including chemical preservatives and proper ventilation, are critical in reducing pest-related damage. Love et al., (2012) further suggest that improved material storage and handling practices can minimize losses. Another key factor is damage due to natural calamities, which received 66% agreement. Extreme weather events such as floods, storms, and earthquakes can lead to extensive material loss and project delays. Compared to gradual weather-related deterioration, natural disasters cause immediate and large-scale damage. Oke et al., (2021) argue that proactive risk management strategies, such as material reinforcement and disaster preparedness, are essential for minimizing losses.

Lastly, damage due to site profile and topography was identified as a significant factor, with 72% agreement. Uneven terrain, poor drainage, and soil instability can contribute to material degradation and inefficient resource use. Ayodele et al., (2020) recommend conducting comprehensive site assessments before construction to anticipate and mitigate these environmental risks.

Discussion of Major Findings

Design and Site Instruction Factors

The study revealed that defective site instructions significantly contribute to material waste, with 66% of respondents agreeing or strongly agreeing. Defective site instructions refer to unclear or incorrect directives given on-site, leading to errors, rework, and excess material usage. This finding aligns with Akinradewo et al., (2020), who emphasized that effective communication is crucial for minimizing construction waste. Additionally, frequent design modifications emerged as a major factor, with 73% agreement. Love et al., (2012) argue that excessive design changes increase costs and inefficiencies. However, while some design alterations are necessary, strategic planning and early-stage decision-making can mitigate their negative effects.

Furthermore, poor design received 58% agreement, suggesting that inadequate architectural and engineering designs contribute to waste due to inaccurate material estimation and defects. Oke et al., (2021) noted that improper designs lead to unnecessary material consumption and project delays. Complex designs had the highest agreement (84%), confirming that intricate architectural plans often result in material overuse. Bello et al., (2024) suggest that simpler designs improve efficiency, reinforcing the study's findings. Inadequate supervision (64% agreement) was another notable concern, with Ayodele et al., (2020) emphasizing that effective oversight enhances material efficiency and compliance with project specifications.

Site Production and Management Factors

The results indicated that poor work attitude and management significantly impact material waste, with 65% agreement. Poor work ethic includes negligence, low motivation, and lack of accountability, while weak management entails ineffective supervision and coordination. Oke et al., (2021) found that these factors often lead to project delays and unnecessary material consumption. Similarly, inadequate training of craftsmen (65% agreement) highlights the need for continuous workforce development. Poorly trained workers are prone to errors, resulting in material rework. Ayodele et al., (2020) argue that structured training programs enhance workmanship and material efficiency.

Material rework was another major concern, with 58% agreement. Rework occurs due to poor craftsmanship, incorrect material application, and design errors, increasing material usage. Akinradewo et al., (2020) found that excessive rework often results from insufficient supervision and poor project planning. Additionally, inexperience among workers received 73% agreement, suggesting that a lack of expertise leads to inefficiencies and waste. Ogunsemi and Aje (2022) emphasize the importance of mentoring programs to improve skills and reduce waste. Interestingly, the change of contractor midway had 68% disagreement, indicating it is not a significant issue in most projects. However, Olatunji et al., (2024) note that in some cases, contractor changes disrupt project continuity and efficiency.

Resource Material Factors

The study identified excessive quantity usage as a significant concern, with 69% agreement. Overestimation during procurement leads to surplus materials, increasing waste. Bello et al., (2024) argue that precise quantity surveying and effective procurement planning are essential to minimizing excess materials. Additionally, the use of inferior materials (72% agreement) contributes to waste due to frequent replacements and structural failures. Love et al., (2012) stress that quality control in procurement processes is crucial to preventing such waste. Poor storage practices (70% agreement) were also highlighted as a key issue, as improper storage exposes materials to damage from environmental conditions. Ayodele et al., (2020) advocate for structured inventory management systems to mitigate these losses. Furthermore, material misuse (58% agreement) and improper handling (72% agreement) contribute to inefficiencies. Workers unfamiliar with material specifications often waste resources through incorrect applications. Oke et al., (2021) suggest that training initiatives and handling protocols can significantly reduce such waste.

Delivery Factors of Material Waste

The delivery of low-quality materials (70% agreement) was a major concern, as substandard materials compromise project integrity, leading to rework. Akinradewo et al., (2020) emphasized that weak quality control in procurement allows defective materials into construction projects. Similarly, poor transportation networks (70% agreement) delay material deliveries, increasing risks of exposure damage. Oke et al., (2021) argue that improving infrastructure and logistics enhances efficiency and minimizes material loss. The most significant issue was the delivery of non-standard material sizes, which received 90% agreement. Non-standard sizes necessitate modifications, leading to excess cutting and waste. Love et al., (2012) advocate for strict adherence to standard specifications to reduce such inefficiencies. Delivery of improperly specified materials had a lower agreement (41%), suggesting it is a less common issue. However, Ayodele et al., (2020) warn that even minor specification errors can disrupt workflow and increase costs. Lastly, improper material packaging (58% agreement) was a moderate concern, as poorly packaged materials are prone to damage. Bello et al., (2024) recommend implementing stricter packaging standards to enhance material usability.

Environmental Factors of Material Waste

Material deterioration due to weather and climate was a major concern, with 64% agreement. Extreme temperatures, moisture, and prolonged exposure to sunlight degrade materials over time. Bello et al., (2024) highlight that inadequate protective measures reduce material lifespan and increase costs. Similarly, damage by insects and pests (64% agreement) poses a challenge, especially for organic materials like wood. Nwaichi et al., (2014) and Nwaichi et al., (2023) emphasize that chemical treatments and proper ventilation are critical for preventing pest-related damage. Damage due to natural calamities (66% agreement) was another significant factor. Events such as floods and earthquakes cause immediate and large-scale material losses. Oke et al., (2021) argue that disaster preparedness and risk mitigation strategies are essential in construction planning. Lastly, site profile and topography received 72% agreement, indicating that uneven terrain, poor drainage, and soil instability contribute to material degradation. Ayodele et al., (2020) recommend thorough site assessments before construction to mitigate environmental risks.

Critique and Future Research

Despite the robustness of these findings, certain limitations exist. The study primarily relied on respondent perceptions, which may introduce subjectivity. Future research could incorporate direct site observations and material tracking technologies for more objective waste assessments. Additionally, while the study identified key waste factors, it did not explore their cost implications. Future studies should examine the financial impact of material waste to develop cost-effective waste reduction strategies. Lastly, further investigation into sustainable construction practices and their effectiveness in waste minimization is recommended.

Fig. 1 identified key factors contributing to material waste in construction, including design changes, poor supervision, inefficient site management, and inadequate material handling. Findings revealed that issues such as low-quality materials, improper storage, and environmental conditions significantly impact material efficiency. Addressing these challenges through improved planning, training, and quality control can enhance sustainability and reduce waste in construction projects.

Fig. 1

Conclusion

Material waste remains a critical issue in the construction industry, affecting project costs, timelines, and environmental sustainability. This study investigates the factors contributing to material waste, including design inefficiencies, site management issues, resource handling, delivery challenges, and environmental conditions. Understanding these factors is essential for improving construction efficiency and promoting sustainable practices.

A structured survey methodology was employed to collect data from construction professionals, using a Likert scale to assess perceptions of material waste contributors. The study analysed factors such as defective site instructions, frequent design changes, inadequate supervision, poor work attitudes, improper material handling, and environmental influences. The results indicate that complex designs (84% agreement), excessive material usage (69%), and environmental conditions such as site topography (72%) are major contributors to waste. Additionally, poor site management, untrained workers, and improper storage practices further exacerbate material losses.

In conclusion, effective waste reduction strategies require improved planning, strict supervision, and adherence to construction best practices. The study highlights the importance of proper training, efficient material storage, and advanced construction technologies like Building Information Modelling (BIM) to minimize waste. While this study provides valuable insights, its reliance on survey data may limit generalizability. Future research should explore real-time waste tracking systems and data-driven waste management strategies to enhance construction sustainability.

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