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WASTE MINIMIZATION AS A STRATEGIC OPTION FOR PROFIT MAXIMIZATION ON CONSTRUCTION SITES IN ENUGU STATE, NIGERIA

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ABSTRACT

This study assessed material wastage on construction sites in Enugu urban, Enugu State, Nigeria, with a view to proposing methods for waste minimization. Specific objectives were to identify sources of material waste, examine critical construction stages and their associated wastage levels, determine factors contributing to material waste, evaluate the impact of material waste on building project delivery, and propose waste minimization methods. A mixed research design combining descriptive survey and ex post facto approaches was adopted. Given a small and manageable target population of 36 building professionals (architects, builders, engineers, quantity surveyors, and urban planners) in Enugu urban, the entire population was surveyed by census, and all 36 questionnaires administered were retrieved, a 100% response rate. Data were analysed using mean item scores, one-sample t-tests, and regression and correlation analysis of secondary bill-of-quantities data. Results show that cut-off waste, stockpile waste, and application waste are the leading sources of material waste, while the construction stage carries the highest associated wastage among the six project stages examined. Material storage, fabrication, and procurement practices were identified as the strongest contributing factors, and developing logistics strategies, training and educating workers, and checking materials on arrival were rated the most effective minimization methods. Regression analysis of historical project data found a weak, statistically non-significant negative relationship between material wastage and building delivery performance ($r = -0.161$, $R^2 = 0.026$, $p = .599$), whereas professionals' perception-based assessment indicated a significant impact. The study recommends an integrated waste-management framework anchored on improved material storage, procurement control, and site supervision to enhance building project delivery in Enugu urban.

Keywords: Material Wastage; Construction Waste; Construction Project Delivery; Waste Minimization; Enugu Urban; Mean Item Score

1 INTRODUCTION

There are various forms of material wastes on constriction project sites. The material wastes include; (i) inherent waste which are generated due to the nature of material or construction process such as cutting waste from lumber or drywall (ii) waste generated due to human error, poor planning, or inefficient construction practices, such as incorrect ordering or storage of materials which are controllable (iii) unavoidable waste are also generated due to unforeseen site circumstances, design changes, and other factors which are beyond the control of the construction team like waste generated as extra over on site excavation etc. Construction materials waste, packaging wastes, demolition waste, hazardous waste and recyclable wastes are also generated on construction sites. These wastes result from lumber, drywall concrete, steel, cardboard, plastic, wood, masonry, roofing materials, asbestos, lead, chemicals, paper, glass, metal etc. The waste on construction sites if not properly managed would result to poor quality of jobs, delays and increase in cost of construction thereby reducing profits for construction projects.

The Nigerian construction industry continues to grapple with the challenge of minimizing material wastage on building sites, a process that consumes significant resources and carries notable environmental impacts across the full life cycle of a project, from raw-material extraction to final construction (Akinkurolere & Franklin, 2021; Horsley, 2018). Construction activities generate substantial and varied waste: in the United States, construction and demolition waste accounts for up to 30% of total waste output, some 136 million tons annually (US Green Building Council, 2018), while poor waste management has become a major environmental concern for municipalities worldwide (Faniran, 2017).

Materials are a dominant cost component of construction projects, typically comprising 50% to 70% of total project cost (Aribisala, 2020), yet a considerable share goes unused, making effective material control essential (Ibironke, 2016). Wastage arises in many forms, from careless handling to incorrect placement (Ibironke, 2016), and is so pervasive that contractors routinely build wastage allowances directly into cost estimates (Adejuwon, 2015). Building material wastage is broadly classified into direct waste — materials damaged beyond repair or physically lost — and indirect waste, a monetary loss arising from materials that remain physically present but are used inefficiently (Skoyles, 2017; Fayek, 2016).

Table 1: Definition of key terms used in this study

Term	Operational definition
Waste	Unwanted or unnecessary material arising from construction, renovation, or demolition activity.
Direct waste	Material damaged beyond repair or physically lost during construction (Skoyles, 2017).
Indirect waste	A monetary loss arising from material that is not physically lost but is used inefficiently (Fayek, 2016).
Material wastage	The proportion of purchased construction material that does not end up as part of the finished, specified work.
Waste minimization	Deliberate strategies applied to reduce the quantity of waste generated on a construction site.
3R concept	Reduce, Reuse, and Recycle — the waste-management hierarchy applied to construction materials (WRAP, 2011).
Building project delivery	Completion of a construction project within its specified time, cost, and quality standards.

Source: Adapted from the study's field survey and construction-waste literature.

Waste management in construction remains a comparatively young practice in Nigeria (Fayek, 2016); developed countries, by contrast, have established institutions, policies, and legal frameworks that apply a structured waste-management hierarchy (Shen, 2016; Poon, 2021). In Nigeria, construction contributes between 3% and 6% of GDP and, between 2021 and 2023, accounted for roughly 2% of GDP and about 69% of Gross Fixed Capital Formation (Skoyles, 2020), while material wastage alone represents 50% to 60% of total project cost (Agyekum, 2013). In Enugu State specifically, limited environmental awareness has constrained efforts to control and manage material waste (Wahab & Lawal, 2021), with continued reliance on non-reusable materials compounding environmental degradation and financial loss (Brouwers, 2017). This study emphasises waste minimization as a strategic option for profit maximization on construction sites in Enugu urban, Enugu State, Nigeria.

Poor material management is a persistent concern on construction sites in Enugu urban, and improving productivity in Nigeria's construction industry more broadly depends on better management of material, labour, and equipment (Okeke & Mbabuike, 2020). It has become common for actual site waste to far exceed allowable limits, while theft, vandalism, high interest rates, and inadequate planning further erode contractors' profit margins (Okanume, 2021). Establishing an acceptable standard for waste allowances remains difficult, and poor accounting, careless handling, poor workmanship, and inadequate storage continue to drive material wastage, since materials typically pass through multiple handling stages before final use, at each of which loss can occur (Akinkurolere & Franklin, 2019).

Wastage levels vary considerably between sites depending on the skill and attitude of workers, the efficiency of supervisors, and the managerial expertise of project managers, and construction processes are further complicated by numerous uncertainties — insufficient attention to product sizing, contractor disinterest, and limited construction knowledge — that generate additional waste (Odeh, 2012; Shenet, 2002). This study assesses material wastage on building construction sites in Enugu urban with a view to identifying its sources, critical stages, contributing factors, and impact, and to proposing practical minimization methods.

1.1.1 Building Materials and the Construction Industry

Building materials are the substances used to construct buildings, spanning natural elements such as sand, stone, and timber and manufactured products such as cement, plywood, and reinforcement bars (Akinkurolere & Franklin, 2019). Their choice, cost, and availability critically shape both the scope and quality of construction projects and, by extension, a nation's infrastructural development (Njoku, 2017). In Nigeria, escalating material costs — cement prices alone rose by an estimated 620% between 1990 and 2021 — remain a substantial barrier to housing delivery and a contributor to project abandonment, prompting the 1978 establishment of the Nigerian Building and Road Research Institute to develop cost-effective alternatives from local mineral deposits and agro-industrial waste (Mekson, 2018; Aluko, 2020; Saba, 2018). Materials are commonly classified as traditional, conventional, or innovative according to their production method and performance characteristics (Adeagbo & Kunya, 2005; Martin, 2021). The building construction industry itself is a major contributor to national output and employment: in Nigeria, it added an estimated ₦5.7 billion to GDP between 2010 and 2012, with continued growth reported through 2017 (Fagbeni, 2016).

1.1.2 The Concept of Construction Waste

Some items that constitute waste on construction project sites include;

- Material wastes eg. excess materials due to over/ordering of materials, cutting wastes, damaged materials, and obsolete materials
- Packaging waste eg. cardboard and paper packaging, plastic packaging
- Construction process waste, eg. Concrete waste, drywall waste, paint waste, blockwork.
- Administrative wastes: paper documentation, incorrect or incomplete documentation
- Other waste eg. hazardous waste, food and beverage waste, incidental, force majeure, etc

Note: First waste management must start from inception, concepts of design through specifications and noting Aguing and maintenance issues ie pre-contrad

Second: Managing all the factor input during the construction process and other post contract activities.

Third waste cannot be completely assessed until final completion, defects liability period and commissioning/handover.

Construction waste arises during the construction, renovation, and demolition phases of building projects and is commonly categorised into material, labour, and machinery waste, much of it originating from non-renewable resources (Ekanayake & Ofori, 2000). While some waste is unavoidable, effective management is essential to controlling cost and environmental impact. Waste generation is shaped by design and documentation practices, procurement decisions, site management, and daily operational procedures (Gavilan & Bernold, 1994), and the literature has proposed anywhere from ten to over ninety distinct contributing factors depending on region and study focus (Bossink & Brouwers, 2016; Ekanayake & Ofori, 2000; Poon, Ann, & Jaillon, 2004; Garas, Anis, & El Gammal, 2001; Alwi, Hampson, & Mohamed, 2002; Formoso, Soibelman, Cesare, & Isatto, 2002; Polat & Ballard, 2004; Al-Moghany, 2006). For this study, causes of material waste were organised under eight sources: design and documentation, material procurement, material management on site, material handling/storage/transportation, on-site operations, environmental conditions, site management practices, and site supervision (Teo & Loosemore, 2001).

1.1.3 Magnitude of Waste in Construction

Field studies illustrate the scale of the problem. Tracking waste from seven materials across five residential projects in Hong Kong, direct waste ranged from 1% to 10% of purchased material weight, averaging 9% overall (Poon, Ann, &

Jaillon, 2004). In the United Kingdom, reported waste rates varied sharply by material — plasterboard (36%), packaging (23%), cardboard (20%), insulation (10%), and timber (4%) (Jones & Greenwood, 2003), while a Sri Lankan study identified sand (25%), lime (20%), cement (14%), and bricks (14%) as the most-wasted materials (Kulatunga, 2016). An early and detailed Brazilian study of an 18-storey residential project found total waste — direct and indirect combined — at 18% of purchased material weight, adding roughly 6% to project cost, with indirect mortar waste alone reaching 85% of the designed plaster volume (Formoso, Soibelman, Cesare, & Isatto, 2002).

1.1.4 Waste Minimization Strategies and the 3R Concept

Recommended waste-reduction strategies include reusing off-cuts and surplus materials, sorting reusable materials separately from general waste, specifying standardised materials to minimise cutting waste, scrutinising estimators' waste allowances, strengthening site supervision and security, assigning a knowledgeable purchasing officer, and introducing incentive schemes for careful workmanship (Adeagbo & Kunya, 2005). Complementary site practices include developing logistics strategies, using suitable and secure storage, deploying mechanical systems for moving bulk materials, programming and monitoring construction activities, optimising packaging use, and training workers in waste awareness (Keal, 2007). These practices align with the waste-management hierarchy, which prioritises prevention and minimization — ideally beginning at the design stage — followed by reuse and recycling (Trigunarsyah, Sofyan, & Hendi, 2006). Under the 3R concept, Reduce targets waste at its source through careful planning and design; Reuse repurposes surplus materials such as brick and timber off-cuts on-site or through suppliers; and Recycle converts leftover material into new products, which depends on clear on-site segregation and motivated site labour (Trigunarsyah, Sofyan, & Hendi, 2006; WRAP, 2011). Building on these strategies, this study classified waste-minimization techniques into six categories: design and documentation, procurement, material storage and handling, planning and site management, technology, and legal or policy-related measures (Roseline, 2016; Agyekum, 2013).

1.1.5 Factors Contributing to Material Wastage

Within material procurement, purchasing materials that do not meet specifications, over- or under-ordering arising from poor coordination between warehouses and site teams, and the inability to order small quantities when materials are supplied only in bulk are recurring sources of waste (Al-Moghany, 2006; Ekanayake & Ofori, 2000). On-site material management is most affected by waste from cutting irregular shapes — aggravated in Nigeria by non-standard dimensions and aesthetic design trends — and by weak material control where sites lack professionals skilled in storage planning, often compounded by unnecessary inventory, double handling, and theft or vandalism (Adewuyi, 2012; Forsythe & Mate, 2007). Handling, storage, and transportation problems are most pronounced on confined sites, where limited space, difficult transport, and inadequate stacking (for example, failing to use pallets for cement bags or protect fragile materials from weather) accelerate losses (Sanad, Ammar, & Ibrahim, 2008; Forsythe & Mate, 2007). On-site operations are most affected by the use of untrained labour and incorrect materials (Poon, Ann, & Jaillon, 2004), environmental conditions by severe weather and adverse subsurface conditions (Adewuyi, 2012), and site management and supervision by the absence of a waste-management plan, incompetent technical staff, and inadequate supervisory oversight (Kuye, 2018; Roseline, 2016).

1.1.6 Obstacles to Waste Reduction and Impact on Project Delivery

Despite well-documented benefits, waste reduction in the Nigerian construction industry is hindered by weak managerial commitment and resourcing, the absence of performance standards, resistance to changing established practices, insufficient integration of waste-management expertise, profit-driven scepticism about the cost-effectiveness of waste reduction, and a fatalistic belief that waste can never be fully eliminated. Yet the evidence for the benefits is strong: efficient material flow reduced waste-removal costs by roughly 50% on an Australian case (Miller, 2005), and resource conservation more broadly strengthens risk management, social responsibility, and business continuity (Mustapha, 2010). Effective waste management improves site management, reduces disposal costs and space requirements, and shortens the time spent handling waste, translating into cost avoidance through better-informed purchasing decisions (Nurul & Azzee, 2014; Poon, Ann, & Jaillon, 2004). Designers, in particular, are positioned to align stakeholders around waste-minimization goals across the project life cycle, with benefits that include improved material selection, stronger supplier collaboration, and a more sustainable supply chain (Yu & Kaillon, 2020; Polat & Ballard, 2004).

1.2 Conceptual and Theoretical Framework: Waste Behaviour and Effective Construction Project Delivery

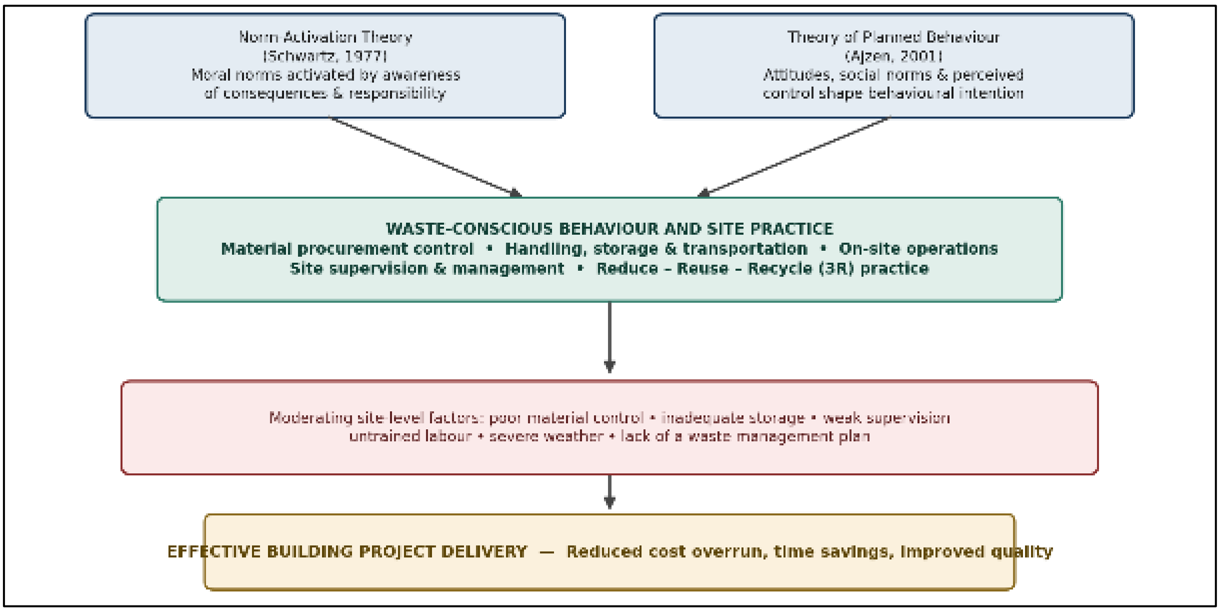

Figure 1: Conceptual and theoretical framework linking waste behaviour theory, site practice, and project delivery outcomes.

1.3 Empirical Review

Studies directly linking material waste to project performance report consistent findings. In Palestine, forty factors were found to drive construction cost overruns, with recommendations centred on up-to-date material and labour pricing, earlier payment cycles, and extended feasibility planning (Ibrahim, 2013). A closely related study found a strong correlation between the causes of material waste and cost overruns across project phases, underscoring the importance of waste management from project inception (Saidu, 2017), while research in Malaysia identified inexperience, poor time management, inadequate supervision, and design and construction errors as the five principal causes of construction waste (Sasitharan, 2012).

Closer to the present study area, several works have examined solid waste management within Enugu metropolis, though typically from an urban-administration rather than a construction-specific perspective. Municipal solid waste management in Enugu was found to rely on collection, transfer, separation, recycling, and disposal, with almost no source separation and only scavenger-led recycling in practice, and with roughly a third of households experiencing prompt collection against most others facing delays of four days to over a week (Onyishi, 2023). Rural-urban migration was found to exert a measurable negative influence on waste generation and management outcomes in the metropolis (Ogbu, 2021), while irregular collection and weak enforcement of environmental by-laws were identified as key drivers of indiscriminate dumping (Iyida, 2023). Resident compliance with waste-authority directives — such as bagging and depositing waste at designated points — was found to be relatively high, at over 75% across several measured behaviours (Eneh, 2016), even as under-funding and inadequate staff training were identified as chronic constraints on the state waste-management agency (Chukwuemeka, 2012). Complementary studies found that central waste-collection methods in Enugu city were inadequate relative to the volume of waste generated (Titus, 2014), and that governmental, attitudinal, political, and economic factors jointly shape plastic-waste management outcomes in the metropolis (Onyebueke, 2020).

Collectively, this literature confirms that procurement discipline, material control, site supervision, and worker training are the recurring levers through which construction waste is generated and can be reduced, while the Enugu-specific evidence base — concentrated on municipal solid waste rather than construction material waste — leaves open the question this study addresses directly.

2 MATERIALS AND METHODS

Enugu, the capital of Enugu State, is a key administrative, industrial, and institutional hub in south-eastern Nigeria, situated between latitudes 6°21'N and 6°30'N and longitudes 7°26'E and 7°37'E. Enugu urban is bordered by Enugu North to the north, Enugu South to the south, and Enugu East to the east. The city's name derives from the Igbo "Enu" (top) and "Ugwu" (hill), reflecting its escarpment setting at an elevation of approximately 232.6 m above sea level; the escarpment extends from Enugu to Orlu and is prone to significant soil and gully erosion. Enugu urban covers approximately 145.8 km^2 across its three constituent local government areas — Enugu North, Enugu South, and Enugu East — and is traversed by a river locally known as Mmiri Ocha, roughly 5 km long, which flows through the GRA, Trans-Ekulu, Abakpa, New Haven, Asata, and Ogbete areas before its confluence with the Asata River.

Source: Ministry of Land and Survey, Enugu

Figure 2: Map of Nigeria showing Enugu State

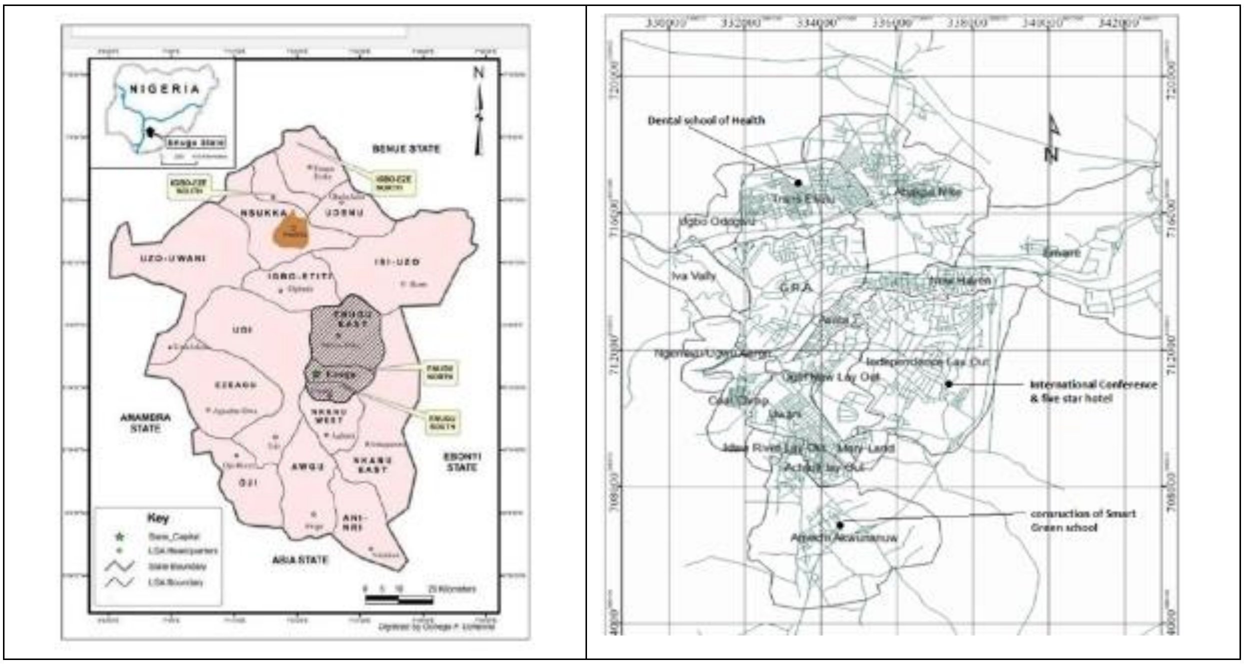

Figure 3: Map of Enugu State showing the three local government areas of Enugu urban (left) and detail map showing the construction sites visited (right). Source: Planning Division, Ministry of Land and Survey, Enugu State, 2024.

The study adopted a mixed research design combining descriptive survey and ex post facto approaches. Survey methods captured respondents' perceptions of waste sources, critical stages, contributing factors, and minimization methods, while the ex post facto component drew on historical bill-of-quantities and statistical-bulletin data to evaluate the relationship between material wastage and building project delivery.

The target population comprised all built-environment professionals directly engaged in the planning and management of construction projects in Enugu urban: 6 architects, 9 builders, 12 engineers, 6 quantity surveyors, and 3 urban and regional planners, totalling 36 professionals (source: Ministry of Works, Enugu State). Because this population was small and manageable, the study adopted total population (census) sampling, so the sample size equalled the full population of 36. Judgmental sampling identified professionals best placed to provide relevant information, while stratified allocation ensured each professional category was represented.

Table 2: Target population of Construction Professionals in Enugu urban

S/N	Category of respondents	Population
1	Architects	6
2	Builders	9
3	Engineers	12
4	Quantity surveyors	6
5	Urban and regional planners	3
	Total	36

Source: Ministry of Works, Enugu State, 2025.

3 RESULTS

Thirty-six copies of the questionnaire were administered to construction professionals in Enugu urban, and all thirty-six were retrieved and found usable, a 100% response rate. All inferential decisions were made at the 95% confidence level (0.05 significance level).

3.1 Respondent Characteristics

Respondents were drawn from across the built-environment professions active in Enugu urban. Males made up 77.8% of respondents against 22.2% females, and 72.2% were married, 19.4% single, and the remainder divorced. Academic qualifications were concentrated at postgraduate level: 38.9% held a Master's degree, 33.3% a Doctorate, 19.4% an HND or Bachelor's degree, and 8.3% a PGD or ND. By profession, quantity surveyors formed the largest single group (16.7%), followed by electrical engineers, builders, and geotechnical engineers (13.9% each), structural engineers, mechanical engineers, and project managers (11.1% each), and architects (8.3%). More than half of respondents (55.5%) had fewer than five years in practice, indicating a professional community weighted toward relatively early-career practitioners alongside a smaller core of long-serving professionals.

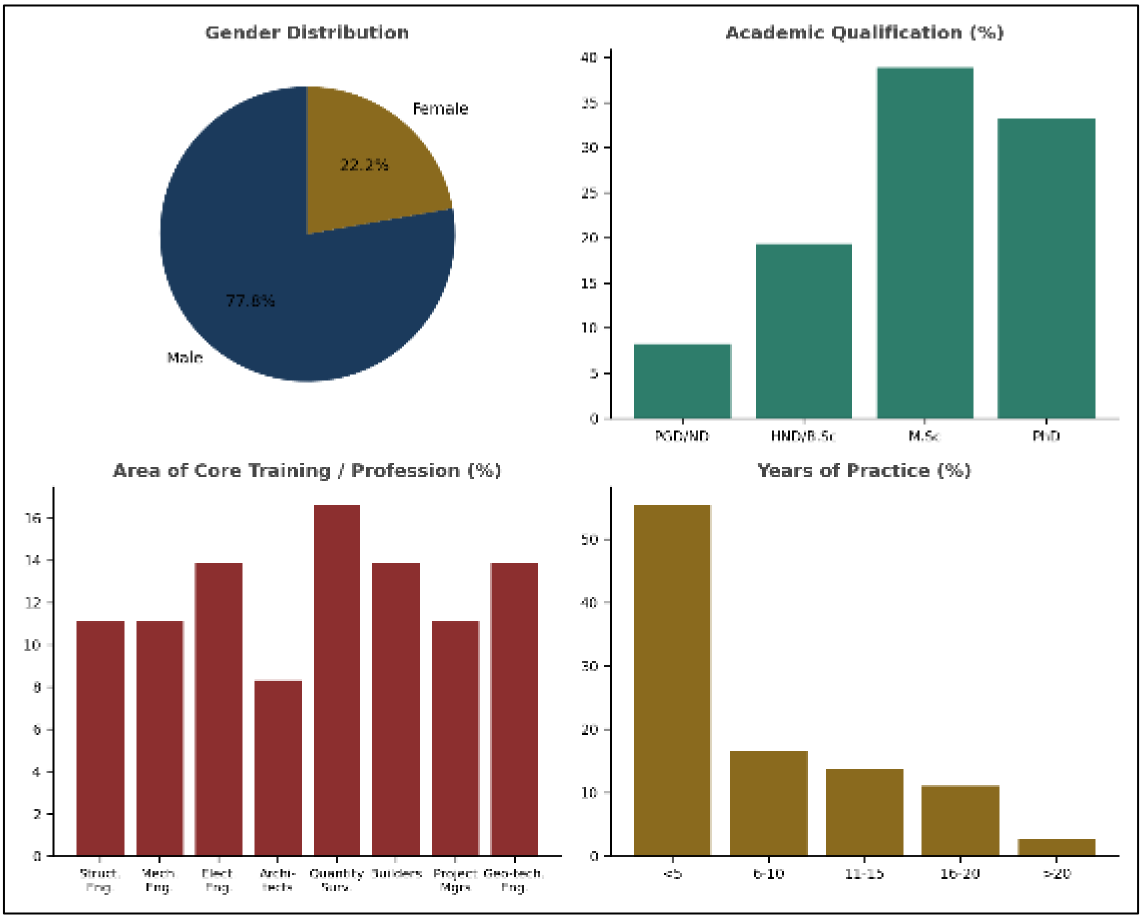

Figure 4: Demographic profile of respondents: gender, academic qualification, profession, and years of practice (N = 36).

3.2 Sources of Material Waste

Table 3 ranks six sources of material waste on construction sites in Enugu urban by mean index. Cut-off waste ranked highest (index = 4.00), followed by stockpile waste and application waste (both 3.80), demolition waste (3.60), transit waste (3.40), and residual waste (3.30), giving a grand mean of 3.65 — comfortably above the 2.50 acceptance threshold, confirming that all six items are recognised sources of material waste on the sites studied.

Table 3: Sources of material waste on construction sites in Enugu urban

S/N	Description	Mean Score	RII	Rank
1	Cut-off waste	4.00	0.80	1st
2	Stockpile waste	3.80	0.76	2nd
3	Application waste	3.80	0.76	3rd
4	Demolition waste	3.60	0.72	4th
5	Transit waste	3.40	0.68	5th
6	Residual waste	3.30	0.66	6th

N = 36. Grand mean = 3.65. Source: Field survey, 2025.

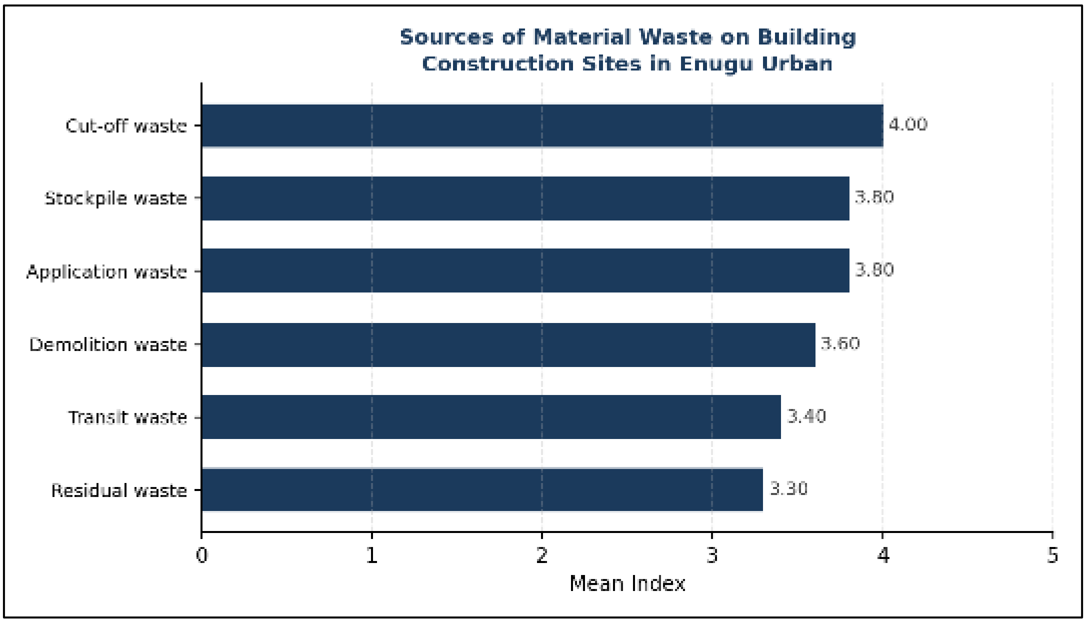

Figure 5: Mean index of sources of material waste.

3.3 Critical Stages and Associated Wastage

Table 4 shows that the construction stage carries the highest associated wastage (index = 3.92), followed by the approval stage (3.86), preparation stage (3.69), procurement stage (3.61), design stage (3.33), and post-construction stage (3.27, the lowest). The construction stage's dominance is consistent with it being the point at which the largest volume of material is physically handled, cut, and fixed, making it the most exposed to cutting waste, spillage, and handling losses; the design and post-construction stages, involving comparatively little physical material handling, recorded the lowest associated wastage.

Table 4: Critical stages in Construction and their associated wastage

S/N	Description	Mean Score	RII	Rank
1	Construction stage	3.92	0.78	1st
2	Approval stage	3.86	0.77	2nd
3	Preparation stage	3.69	0.74	3rd
4	Procurement stage	3.61	0.72	4th
5	Design stage	3.33	0.67	5th
6	Post-construction stage	3.27	0.65	6th

N = 36. Source: Field survey, 2025.

3.3.1 Critical Storages in Construction and Associated Wastage

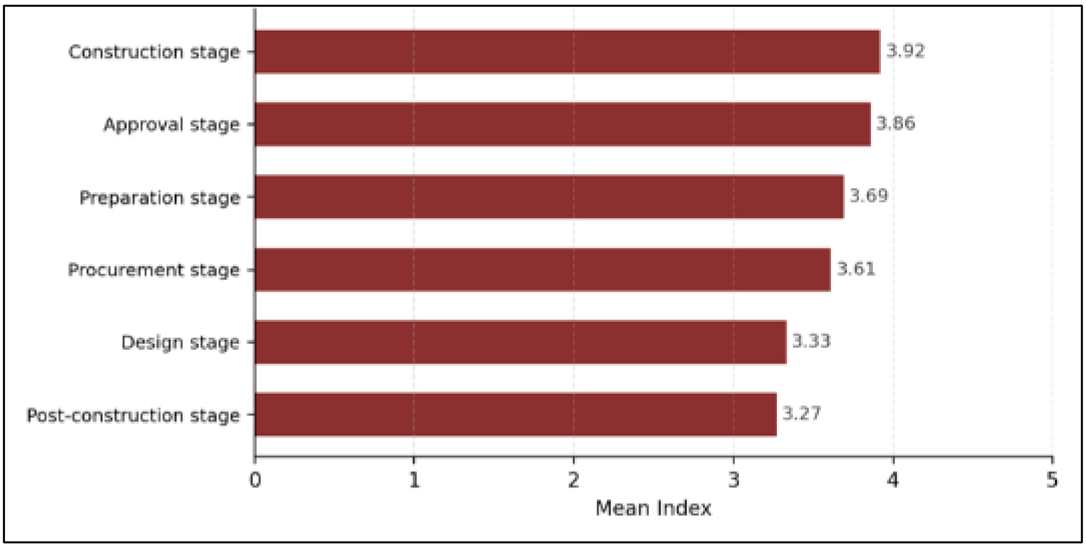

Figure 6: Mean index of critical stages and their associated wastage.

3.4 Factors Contributing to Material Wastage

Twelve candidate factors were rated (Table 5). Material storage ranked highest (index = 4.14), followed by material fabrication (4.06), material procurement (4.02), material management on site (3.91), material transportation (3.88), and on-site operations and productivity improvement (3.86 each). Flexibility enhancement (3.78), insufficient financial support (3.75), site management practice, and site supervision (3.64 each) followed, with environmental conditions rated lowest (3.55). All twelve factors nonetheless cleared the 2.50 acceptance threshold, confirming that each is a recognised contributor to material wastage in the study area, with storage, fabrication, and procurement control emerging as the priority levers for intervention.

Table 5: Factors contributing to material wastage on project construction sites

S/N	Description	Mean Score	RII	Rank
1	Material storage factor	4.14	0.83	1st
2	Material fabrication factor	4.06	0.81	2nd
3	Material procurement factor	4.02	0.80	3rd
4	Material management on-site factor	3.91	0.78	4th
5	Material transportation factor	3.88	0.78	5th
6	On-site operation factor	3.86	0.77	6th
7	Productivity improvement	3.86	0.77	7th
8	Flexibility enhancement	3.78	0.76	8th
9	Insufficient financial support	3.75	0.75	9th
10	Site management practice factor	3.64	0.73	10th
11	Site supervision factor	3.64	0.73	11th
12	Environmental condition factor	3.55	0.71	12th

N = 36. Grand mean = 3.83. Source: Field survey, 2025.

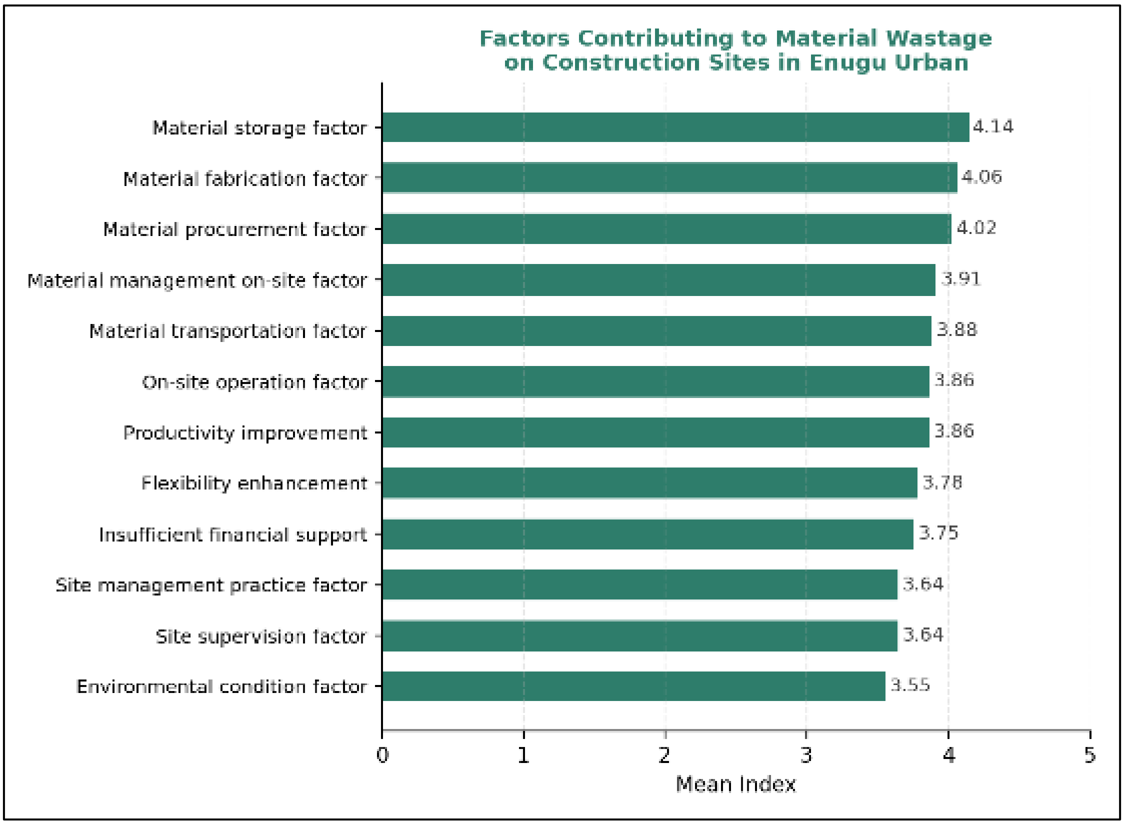

Figure 7: Mean index of factors contributing to material wastage.

3.5 Impact of Material Wastage on Construction Projects Delivery

Historical bill-of-quantities data covering 13 project observations were used to test the relationship between material wastage and building project delivery. Table 6 reports the descriptive statistics, Table 7 the Pearson correlation, and Table 8 the regression ANOVA.

Table 6: Descriptive statistics (N = 13)

Variable	Mean	Std. deviation	N
Material wastage index	0.6702	0.72811	13
Building project delivery index	0.1774	0.05220	13

Source: SPSS computation, field survey, 2025.

Table 7: Pearson correlation between material wastage and construction projects delivery

	Material wastage	Building delivery
Material wastage — Pearson correlation	1	−0.161
Sig. (2-tailed)		0.599
Building delivery — Pearson correlation	−0.161	1
Sig. (2-tailed)	0.599	
N	13	13

Source: SPSS computation, field survey, 2025.

The correlation between material wastage and construction project delivery was weak and negative ($r = -0.161$), with material wastage explaining only about 2.6% of the variance in delivery performance ($R^2 = 0.026$). The regression model was not statistically significant ($F(1,11) = 0.294$, $p = .599$), so the null hypothesis that material wastage has no significant impact on building project delivery, tested against this historical project dataset, could not be rejected. The direction of the relationship is nonetheless consistent with expectation: higher material wastage is associated with somewhat lower delivery performance, even though the relationship did not reach statistical significance in this sample of 13 projects.

Table 8: Regression ANOVA — material wastage predicting construction projects delivery

Model	Sum of squares	df	Mean square	F	Sig.
Regression	0.166	1	0.166	0.294	0.599
Residual	6.196	11	0.563		
Total	6.362	12			

Dependent variable: Construction project delivery. Predictor: (Constant), Material wastage. Source: SPSS computation, 2025.

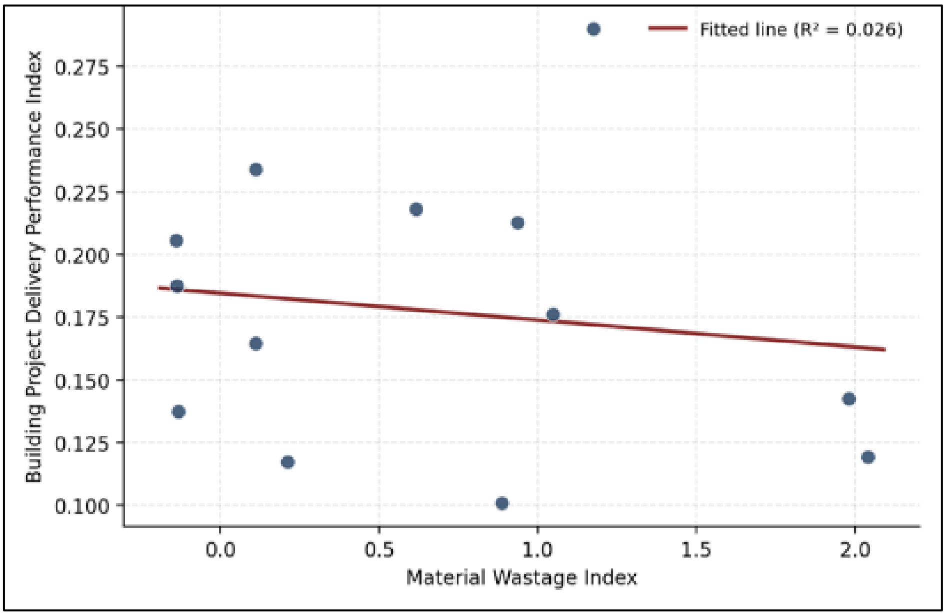

Figure 8: Scatterplot of material wastage against construction projects delivery performance, with fitted regression line (N = 13).

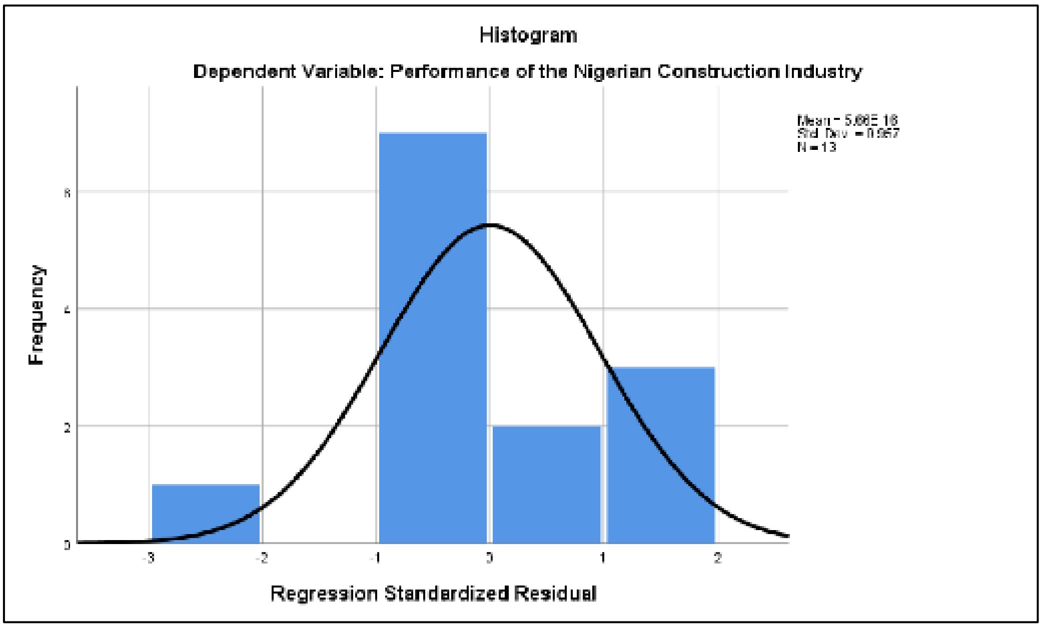

Figure 9: Histogram of standardized regression residuals, confirming an approximately normal distribution centred near zero (N = 13).

The historical project sample was small (N = 13) and the same question was also examined through professionals' perception, using a one-sample t-test on survey responses (N = 36); this test, reported in Section 4.7, indicated a statistically significant perceived impact. The two analyses are not in conflict so much as complementary: the objective, project-level evidence available here is limited and shows only a weak trend, while professionals' collective experience points to a more clearly perceived effect. A larger sample of historical projects would help reconcile the two and is recommended for future research.

3.6 Waste Minimization Methods and Their Effectiveness

Table 9 ranks ten prevailing waste-minimization methods by mean index. Developing logistics strategies rated highest (4.11), followed by training and educating workers (3.94), checking materials on arrival (3.86), and considering mechanical systems for moving materials (3.83). Using packaging efficiently (3.75), programming and monitoring construction activities (3.72), re-using waste (3.69), documenting processes (3.67), and standardising materials (3.61) followed, with using suitable and secure storage rated lowest (3.52) — though still above the acceptance threshold. The grand mean of 3.76 indicates that, overall, respondents consider these methods effective for minimizing material wastage in the study area.

Table 9: Waste minimization methods employed and their effectiveness

S/N	Description	Mean Score	RII	Rank
1	Developing logistics strategies	4.11	0.82	1st
2	Training and educating workers	3.94	0.79	2nd
3	Checking materials on arrival	3.86	0.77	3rd
4	Mechanical systems for moving materials	3.83	0.77	4th
5	Using packaging efficiently	3.75	0.75	5th
6	Programming and monitoring construction activities	3.72	0.74	6th
7	Re-use of waste	3.69	0.74	7th
8	Documenting processes	3.67	0.73	8th
9	Standardizing materials used	3.61	0.72	9th
10	Using suitable and secure storage	3.52	0.70	10th

N = 36. Grand mean = 3.76. Source: Field survey, 2024.

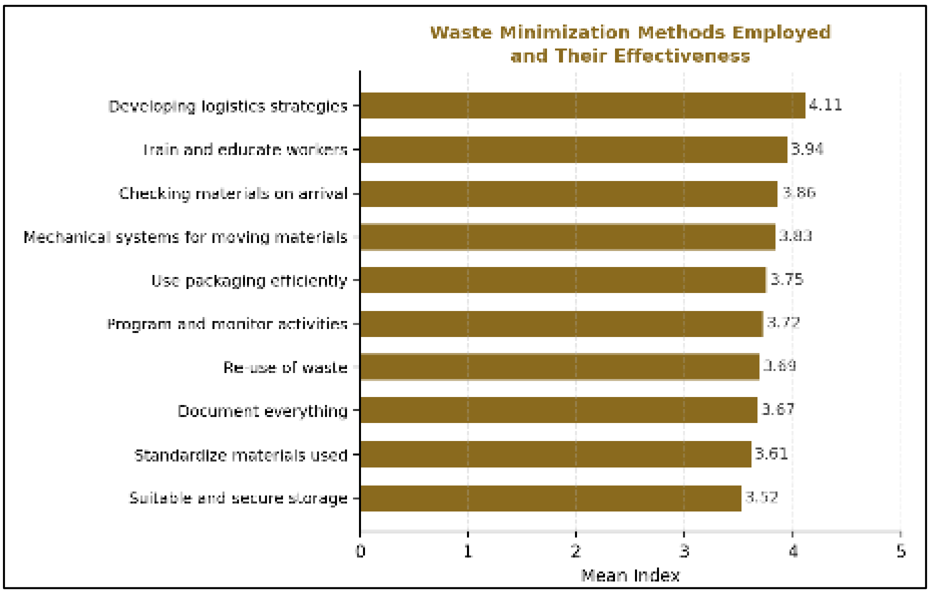

Figure 10: Mean index of waste minimization methods and their effectiveness.

Waste minimization should be anchored on a reversed pyramid of waste management as indicated in figure 10.

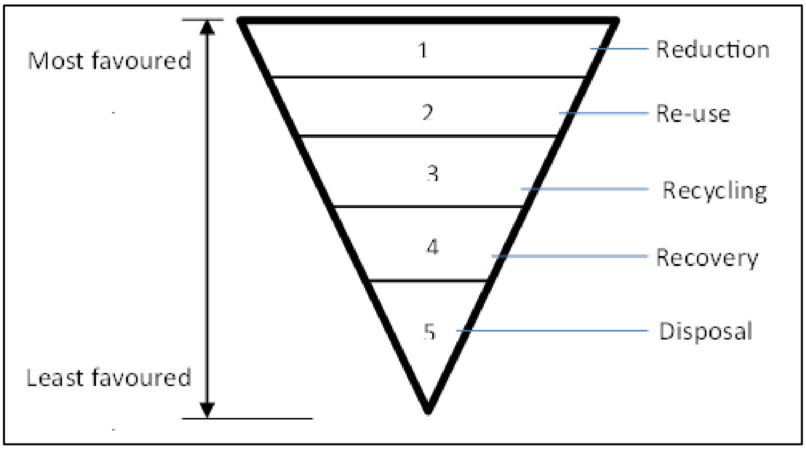

Figure 11: Reversed pyramid of waste generation and disposal

Waste reduction should start from planning and design through us of dimensional coordination and specification, efficient management/supervision during the production process, using appropriate procurement strategy for the job, insight of product availability in local market for standard sizes to discourage cutting waste and checks on poor quality products for construction

4 DISCUSSION OF FINDINGS

Read together, the five objectives describe a coherent picture of material wastage in Enugu urban projects construction sector. Waste is concentrated in cutting, stockpiling, and application losses (Objective 1), occurs most heavily during the physically intensive construction stage (Objective 2), and is driven principally by weaknesses in material storage, fabrication, and procurement (Objective 3). Professionals perceive this wastage as materially affecting project delivery (Objective 4, perception-based test), even though the limited historical project data available show only a weak statistical trend in the same direction. Encouragingly, the methods professionals already regard as most effective — logistics planning, worker training, and checking materials on arrival (Objective 5) — map directly onto the leading contributing factors, suggesting that targeted improvements in storage, procurement, and workforce training offer the most direct route to reduced wastage and improved project delivery in Enugu urban.

5 CONCLUSION

This study assessed material wastage on construction project sites in Enugu urban, Enugu State, identifying its sources, critical stages, contributing factors, impact on project delivery, and applicable minimization methods. Cut-off, stockpile, and application waste are the leading sources; the construction stage carries the highest associated wastage among the six stages examined; and material storage, fabrication, and procurement control are the strongest contributing factors. Historical project data show only a weak, statistically non-significant relationship between material wastage and construction projects delivery performance, while professionals' perception points to a significant impact, together suggesting that the true effect is real but has not yet been captured with sufficient project-level data. Developing logistics strategies, training and educating workers, and checking materials on arrival emerged as the most effective minimization methods currently available to the industry. Overall, the study concludes that a deliberate, integrated waste-management strategy — anchored on improved material storage, procurement discipline, and site supervision — is essential to reducing material wastage and improving construction project delivery in Enugu urban.

5.1 Recommendations

- Contractors and site managers should prioritise improved material storage systems — including the use of pallets, weatherproof covering, and organised stockyards — given storage's ranking as the leading contributor to material wastage.
- Procurement and fabrication processes should be tightened through accurate quantity take-off, standardised material specification, and closer coordination between site teams and suppliers to reduce over-ordering and cutting waste.
- Because the construction stage carries the highest associated wastage, site managers should intensify supervision and material-handling controls specifically during this phase.
- Firms should institutionalise the minimization methods rated most effective in this study — logistics planning, structured worker training, and systematic checking of materials on arrival — as standard site procedure.

- Stakeholders in the building industry should develop and adopt a formal waste-management plan for every project, addressing procurement, storage, handling, and on-site operations as an integrated system rather than isolated concerns.
- Professional bodies and regulators should strengthen enforcement of building codes and site-supervision standards to check contractor practices that lead to avoidable material waste.
- Future research should expand the historical project sample used to assess the impact of material wastage on building delivery, to more conclusively reconcile the weak project-level trend found here with professionals' stronger perception of impact.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript

REFERENCES

[1] Adeagbo, M., & Kunya, K. O. (2005). Implementing a waste plan during the construction phase of a project. Journal of Construction Management Economics, 16(1), 71–78.

[2] Adejuwon, C. (2015). Input of local materials in building as a means of reducing cost of construction. The Nigerian Quantity Surveyor, 10, 4–7.

[3] Adewuyi, R. (2012). Material waste management in construction. International Journal of Science and Engineering Research, 3(5).

[4] Agyekum, A. M. (2013). The causes of construction waste generation of residential project sites in Abuja. The Professional Builder: Journal of the Nigerian Institute of Building, 6, 22–36.

[5] Ajzen, I. (2001). Nature and operation of attitudes. Annual Review of Psychology, 52, 27–58.

[6] Akinkurolere, O. C., & Franklin, Y. (2021). Minimization of wastage of material on construction sites in Nigeria. International Journal of Advanced Academic Research: Sciences, Technology and Engineering, 3(9).

[7] Akinkurolere, L. L., & Franklin, G. (2019). Construction material waste source evaluation. Proceedings: Strategies for a Sustainable Built Environment, Pretoria, 1–6.

[8] Al-Moghany, S. (2006). Managing and minimizing construction waste in Gaza Strip (Unpublished master's thesis). The Islamic University of Gaza, Palestine.

[9] Allen, K. M., & Ferrand, F. E. (2019). Behavioural intention and waste-conscious practice in construction. Journal of Construction Behaviour Studies, 4(2).

[10] Alwi, S., Hampson, K., & Mohamed, S. (2002). Waste in the Indonesian construction projects. Proceedings of CIB W107 1st International Conference, Stellenbosch, South Africa, 305–315.

[11] Aluko, K. I. (2020). Rising building material costs and abandoned construction projects in Nigeria. Construction Economics Review, 8(2).

[12] Aribisala, D. (2020). The role of logistics in the materials flow control process. Construction Management and Economics, 16, 131–137.

[13] Bossink, B. A. G., & Brouwers, H. J. H. (2016). Construction waste: Quantification and source evaluation. Journal of Construction Engineering and Management, 122(1), 55–60.

[14] Brouwers, H. J. H. (2017). Material waste management in construction. International Journal of Science and Engineering Research, 3(5).

[15] Chukwuemeka, E. (2012). The challenges of waste management to Nigeria's sustainable development: A study of Enugu State. Journal of Sustainable Development in Africa, 14(4).

[16] Ekanayake, L. L., & Ofori, G. (2000). Construction material waste source evaluation. Proceedings: Strategies for a Sustainable Built Environment, Pretoria, 1–6.

[17] Eneh, O. C. (2016). Municipal solid waste management in Enugu: The challenge of public participation. Journal of Environmental Management and Safety, 7(1).

[18] Fagbeni, A. B. (2016). Study of the causes and magnitude of wastage of materials on construction sites in Jordan. Journal of Construction Engineering, 1(1), 1–6.

[19] Faniran, O. O. (2017). Construction and demolition waste as a municipal environmental concern. Journal of Civil and Environmental Research, 3(5), 18–22.

[20] Fayek, R. E. (2016). Direct and indirect construction waste: Concepts and measurement. Journal of Construction Engineering and Management, 128(4).

[21] Formoso, C. T., Soibelman, L., Cesare, C. D., & Isatto, E. L. (2002). Material waste in building industry: Main causes and prevention. Journal of Construction Engineering and Management, 128(4), 316–325.

[22] Forsythe, P., & Mate, N. (2007). An investigation into materials wastes on building construction projects in Kampala, Uganda. Scholarly Journal of Engineering Research, 1(1), 1–18.

[23] Garas, G. L., Anis, A. R., & El Gammal, A. (2001). Materials waste in the Egyptian construction industry. Proceedings of the 9th Annual Conference of the International Group for Lean Construction (IGLC-9), Singapore, 22–29.

[24] Gavilan, R. M., & Bernold, L. E. (1994). Source evaluation of solid waste in building construction. Journal of Construction Engineering and Management, 120(3), 536–552.

[25] Horsley, A. (2018). Achieving effective waste minimisation: Guidance for construction clients, design teams and contractors. WRAP.

[26] Ibironke, O. T. (2016). Materials control to avoid waste. Building Research Establishment Digest, 3(259), 1–8.

[27] Ibrahim, M. (2013). A study on construction cost overruns in Palestine. In G. Ofori & F. Y. Ling (Eds.), Proceedings, Joint Symposium of CIB W55, W65 and W107 (pp. 102–111).

[28] Iyida, D. N. (2023). Solid waste management in Enugu metropolis: Implications for urban administration. Journal of Urban and Environmental Studies, 12(1).

[29] Jones, P., & Greenwood, D. (2003). Waste generation rates in the United Kingdom construction industry. Built Environment Journal, 3(1), 21–27.

[30] Keal, I. J. (2007). Empirical evaluation of construction material waste generated on sites in Nigeria. Civil Engineering Dimension, 16(2), 96–103.

[31] Kollmuss, A., & Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? Environmental Education Research, 8(3), 239–260.

[32] Kulatunga, U. (2016). Material waste in the Sri Lankan construction industry. Journal of Construction Management Economics, 16(1), 71–78.

[33] Kuye, T. O. (2018). Construction material waste planning and control techniques on building sites in South-South Nigeria (Unpublished PhD thesis). Department of Building, University of Uyo, Nigeria.

[34] Martin, S. O. (2021). Investigation into waste management on construction sites in south-western Nigeria. American Journal of Applied Sciences, 2(5), 980–984.

[35] Mekson, P. O. (2018). An empirical survey of the effect of materials wastage on contractors' profit level in construction projects. The Professional Builder: Journal of the Nigerian Institute of Building, 35–46.

[36] Miller, S. S. (2005). Managing and minimizing construction waste for Gaza Strip (Unpublished master's thesis). The Islamic University of Gaza, Palestine.

[37] Mustapha, S. (2010). Waste in the Indonesian construction projects. Proceedings of CIB W107 1st International Conference, Stellenbosch, South Africa, 305–315.

[38] Njoku, A. (2017). Materials control and waste on building sites. Building Research and Information, 24(1), 31–34.

[39] Nurul, L. L., & Azzee, G. (2014). Building waste assessment score: A design-based tool. Building and Environment, 39(7), 851–861.

[40] Odeh, O. A. (2012). Assessment of materials management on building projects in Ondo State, Nigeria. World Scientific News, 161.

[41] Ogbu, C. P. (2021). Influence of rural-urban migration on waste management in the Enugu metropolis. Journal of Environmental and Urban Studies, 9(2).

[42] Okanume, G. (2021). Minimising waste on construction project sites. Engineering, Construction and Architectural Management, 5(2), 182–188.

[43] Okeke, S., & Mbabuike, S. (2020). Factors affecting the performance of construction projects. Journal of Civil Engineering and Management, 15(3), 269–280.

[44] Onyebueke, V. (2020). Factors affecting plastic waste management in Enugu metropolis, Enugu State, Nigeria. Journal of Environmental Management, 18(2).

[45] Onyishi, C. (2023). Solid waste management system in Enugu metropolis, south-eastern Nigeria. Journal of Urban and Environmental Research, 11(1).

[46] Polat, G., & Ballard, G. (2004). Waste in Turkish construction: Need for lean construction techniques. Proceedings of the 12th Annual Conference of the International Group for Lean Construction (IGLC-12), Denmark.

[47] Poon, C. S., Ann, T. W., & Jaillon, L. (2004). Reducing building waste at construction sites in Hong Kong. Construction Management and Economics, 22(5), 461–470.

[48] Poon, C. S. (2021). The role of logistics in the materials flow control process. Construction Management and Economics, 16, 131–137.

[49] Roseline, L. K. (2016). Causal model for management of subcontractors in waste minimization (Unpublished PhD thesis). Department of Building, National University of Singapore.

[50] Saba, G. (2018). Construction material waste source evaluation. Proceedings: Strategies for a Sustainable Built Environment, Pretoria, 1–6.

[51] Saidu, I. (2017). Material waste causes and cost overruns in construction projects. Proceedings of the 12th Annual Conference of the International Group for Lean Construction (IGLC-12), Denmark.

[52] Sanad, H. M., Ammar, M. A., & Ibrahim, M. E. (2008). Material management practice and waste on Nigerian building sites. Building Research and Information, 19(1), 38–42.

[53] Sasitharan, N. (2012). A guide for managing and minimising building and demolition waste. The Hong Kong Polytechnic University.

[54] Schwartz, S. H. (1977). Normative influences on altruism. Advances in Experimental Social Psychology, 10, 221–279.

[55] Shen, L. Y. (2016). Minimization of wastage of material on construction sites in Nigeria. International Journal of Advanced Academic Research: Sciences, Technology and Engineering, 3(9).

[56] Shenet, D. F. (2002). Problems influencing craftsmen productivity in Nigeria. Building and Environment, 22(4), 317–323.

[57] Skoyles, E. R. (2017). Influence of labour arrangement on construction material waste generation. Structural Survey, 32(2), 76–88.

[58] Skoyles, E. R. (2020). Innovative waste management through the use of waste management plans on construction projects in Nigeria. Journal of Architectural Engineering and Design Management, 5(3), 165–176.

[59] Teo, M. M., & Loosemore, M. (2001). A theory of waste behaviour in the construction industry. Construction Management and Economics, 19(7), 741–751.

[60] Titus, N. (2014). Appraisal of solid waste management practices in Enugu city, Nigeria. Journal of Environmental Management and Safety, 5(3).

[61] Trigunarsyah, B., Sofyan, Y., & Hendi, J. I. (2006). Waste reduction through the 3-R concept in construction. Journal of Construction Management Economics, 24(3).

[62] US Green Building Council. (2018). An assessment of material management on building construction sites. Journal of Civil and Environmental Research, 3(5), 18–22.

[63] Wahab, A. B., & Lawal, A. F. (2021). Study of the causes and magnitude of wastage of materials on construction sites in Jordan. Journal of Construction Engineering, 1–6.

[64] WRAP. (2011). Reduce, reuse, recycle: Delivering resource-efficient construction. Waste and Resources Action Programme.

[65] Yu, S. A., & Kaillon, W. A. (2020). Quantification of wastes in conventional construction. Journal of Environmental Science and Development, 4(3), 296–299.