

Evaluating The Impact of Cement Waste Recycling On Production Cost in Nigeria Cement Companies

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Abstract

The study investigated the impact of cement waste recycling on production cost in Nigerian cement manufacturing companies. Considering the growing need for sustainable industrial practices and cost efficiency in cement production, this study is guided the three objectives; to determine the extent of recycling implementation, assess its effect on raw material usage, and evaluate its role in reducing waste disposal costs. A descriptive survey design was employed, targeting a population of 610 stakeholders from three major cement companies; Dangote Cement Plc, Lafarge Africa Plc, and BUA Cement Plc. Using Krejcie and Morgan's formula, a sample size of 236 was determined and proportionally distributed across the companies using stratified random sampling. Data were collected through a structured questionnaire. The findings revealed a high level of implementation of cement waste recycling, with a grand mean of 4.27 on 5.0 scale, indicating its integration into routine operations and infrastructure. Regarding raw material cost, the analysis showed that recycling significantly reduced the reliance on virgin inputs, reflected in a grand mean of 4.34. Additionally, the impact on waste disposal costs was marked, with a grand mean of 4.43, affirming that recycling contributed to lower handling and regulatory expenses. Hypothesis testing using one-sample t-tests confirmed that all three null hypotheses were rejected at a 0.05 significance level, providing strong evidence of significant implementation and cost-reducing impacts of recycling practices in the sector. Conclusively, the study established that cement waste recycling is widely implemented and plays a vital role in lowering both raw material and waste disposal costs.

Keywords: Cement waste recycling, Cost efficiency, Production cost, Raw material usage, Sustainable industrial practices

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Introduction

Background of the Study

Cement manufacturing remains a cornerstone of infrastructural development globally, especially in emerging economies such as Nigeria. With increasing urbanization, Nigeria's demand for cement has surged, driven by construction activities across residential, commercial, and industrial sectors. However, this rapid growth in production has led to significant environmental and economic concerns. Cement production is both resource-intensive and waste-generating, contributing not only to greenhouse gas emissions but also to the accumulation of solid industrial waste that requires effective management (Benjamin & Benjamin, 2023).

Among the major challenges faced by cement manufacturing companies is the handling of cement waste generated during production, transportation, and packaging. Traditionally, such waste has been disposed of in landfills, creating environmental hazards and financial burdens related to disposal costs. In recent years, however, waste recycling has emerged as a promising strategy to mitigate these impacts. The recycling of cement waste involves reprocessing leftover, rejected, or unused cement materials back into the production cycle as alternative raw materials or additives. According to Tank and Joshi (2019), this approach is seen as a dual-benefit strategy; minimizing environmental degradation while potentially reducing production costs.

A key component of the research problem is the limited implementation and inconsistent adoption of cement waste recycling practices across Nigerian cement companies. Despite global advances in sustainable cement manufacturing, many Nigerian firms still rely on conventional production methods that are neither cost-effective nor environmentally sustainable (Olawale, Shittu, & Abdullateef, 2022). This suggests a gap in the practical application of green production strategies and raises questions about the factors influencing such operational decisions. The economic implications of waste recycling in cement production are particularly significant. Studies have shown that integrating recycled materials can reduce dependence on virgin raw materials, lower procurement costs, and enhance overall resource efficiency (Sharkawi, 2020). For instance, the use of alternative raw materials such as corncob ash and construction debris has been proven to maintain or even improve the quality of cement-based products while reducing material costs (Oyebisi et al., 2017). However, empirical data on cost savings from cement waste recycling specific to Nigerian companies remains sparse, indicating a critical area for further investigation.

The cost of disposing of cement waste in Nigeria is influenced by multiple factors. While specific figures for disposing of cement waste in Nigeria cement companies are not universally available due to variability across regions and companies, estimates suggest that landfill disposal could range from approximately 5,000 to 15,000 Naira per ton depending on location and regulatory compliance costs. Evidence suggests that recycling waste in-house could significantly cut down these costs. This method is known as Geocycle and it is already adopted by Lafarge Company, an innovative approach that has gained traction by the company and it is part of its operations across its business units in Ewekoro, Ogun state and Mfamosing, Cross River state respectively. In Geocycle, waste materials including waste cement are utilized as alternative fuels or raw materials in cement kilns. This method not only helps in

reducing the volume of waste sent to landfills but also recovers energy from the waste during the cement production process. By integrating waste into their production cycle, companies can minimize their environmental footprint while enhancing resource efficiency. In a study examining the structural viability of construction materials made from recycled nylon and plastic waste, researchers found that such materials not only offered economic advantages but also improved durability and water resistance compared to traditional cement products (Olawale, Shittu, & Abdullateef, 2022). These findings highlight the potential for cement waste recycling to become a cost-saving measure.

Globally, the cement industry is undergoing a transformation towards greener practices by embracing circular economy models, where waste from one process becomes input for another. In countries with advanced waste management systems, the cement industry has become a major player in diverting industrial waste from landfills to kilns as raw material and fuel alternatives (He et al., 2021). These practices have not only reduced production costs but also enhanced environmental compliance. In contrast, most Nigerian cement sector remains in the early stages of integrating these innovations, due in part to regulatory gaps, limited technical infrastructure, and low awareness among industry stakeholders.

This highlights a critical gap in both academic literature and industrial practice. While sustainable waste management solutions are gaining global momentum, most Nigerian cement companies lack empirical data to justify the economic benefits of recycling cement waste. As a result, many firms continue to bear unnecessary production and disposal costs. If unaddressed, the continued neglect of recycling opportunities will not only inflate operational costs but also exacerbate environmental concerns associated with cement waste disposal. This study seeks to fill this gap by evaluating the extent of recycling implementation and its impact on raw material and waste management costs.

Statement of the Problem

The cement industry plays a critical role in supporting infrastructural development and economic growth in Nigeria. As demand for cement continues to rise in response to rapid urbanization and industrial expansion, so does the pressure on natural resources and the volume of production-related waste. Cement manufacturing is resource-intensive, relying heavily on raw materials such as limestone and clay, and generates substantial waste through spillage, rejected batches, and packaging residues. This not only escalates production costs but also contributes to environmental degradation through inefficient waste disposal.

Despite global shifts toward sustainable manufacturing, the integration of cement waste recycling into production processes in Nigerian cement companies remains unclear. The central issue this study addresses is the cost implication of implementing waste recycling in cement production factories in Nigeria. Specifically, it seeks to examine how recycling practices affect raw material expenses and waste disposal costs; two key drivers of production expenditure. Existing studies in Nigeria have primarily focused on the technical feasibility of using alternative materials, yet few have assessed the direct economic implications of cement waste recycling on production costs.

This highlights a critical gap in both academic literature and industrial practice. While sustainable waste management solutions are gaining global momentum, most Nigerian cement companies lack empirical data to justify the economic benefits of recycling cement waste. As a result, many firms continue to bear unnecessary production and disposal costs. If unaddressed, the continued neglect of recycling opportunities will not only inflate operational costs but also exacerbate environmental concerns associated with cement waste disposal. This study seeks to fill this gap by evaluating the extent of recycling implementation and its impact on raw material and waste management costs.

Aim and Objectives of the Study

The study aims to evaluate the impact of cement waste recycling on production cost in Nigeria cement companies. The specific objectives of the study are to;

- i. To determine the extent to which cement waste recycling is implemented in Nigeria cement manufacturing companies using three notable companies
- ii. To examine the effect of cement waste recycling on the cost of raw materials used in cement production.

Research Question

In view of the objectives set out, this study seeks to specifically answer the following research questions:

- i. To what extent is cement waste recycling implemented in Nigerian cement manufacturing companies?
- ii. What effect does cement waste recycling have on the cost of raw materials used in cement production?

Statement of Hypothesis

The study is guided by the following hypotheses;

- i. H₀₁: There is no significant implementation of cement waste recycling practices in Nigerian cement manufacturing companies.
- ii. H₀₂: Cement waste recycling has no significant effect on the cost of raw materials used in cement production.

Significance of the Study

The study has considerable benefits for multiple stakeholders within and beyond the Nigerian cement industry.

Policy makers and government agencies tasked with industrial development and environmental regulation will also benefit from this study. The research findings can support the formulation of more effective waste management policies and incentivize sustainable manufacturing practices within the construction materials sector.

Academic researchers and scholars in the fields of environmental science, industrial engineering, and sustainable development will find the study valuable for advancing knowledge on cost-efficient recycling methods specific to

emerging economies like Nigeria. It contributes to closing a notable gap in literature regarding the financial implications of waste recycling in the cement industry.

Scope of the Study

The study is focused on evaluating the impact of cement waste recycling on production costs in Nigerian cement manufacturing companies. Geographically, the study is confined to Nigeria, with particular attention to selected major cement-producing regions including Cross River, Kogi, and Edo States. The study specifically examined three prominent cement manufacturing companies as case studies: Dangote Cement Plc (Obajana Plant), Lafarge Africa Plc (Mfamosing Plant), and BUA Cement Plc (Okpella Plant). These companies were chosen due to their scale of operations, national economic relevance, and accessibility for data collection.

Review of the Related Literature

Conceptual Review

Cement Waste

Cement waste is a critical by-product of the cement manufacturing process, encompassing a range of solid residues, particulate matter, and unused materials generated at various stages of production. In the context of Nigerian cement manufacturing, understanding the concept of cement waste is fundamental to addressing operational inefficiencies, environmental concerns, and the escalating cost pressures facing the industry. This section provides a detailed conceptual exploration of cement waste as it relates to the current study, which evaluates the impact of cement waste recycling on production costs.

Cement waste comprises all unused, residual, or discarded materials generated during the production, handling, transportation, and application of cement. These wastes may include cement kiln dust (CKD), clinker dust, packaging residues, expired or hardened cement, and returned concrete. The major source of such waste arises from high-temperature kiln processes, grinding, blending, and storage systems where material losses are inherent due to inefficiencies and mechanical limitations.

In particular, cement kiln dust is a significant waste stream. CKD is a fine-grained, solid material generated during the clinker cooling and dust collection processes. It consists primarily of oxidized mineral particles and trace alkalis, and its management poses both environmental and operational challenges. In Nigeria, the inefficiencies in capturing and recycling CKD and other particulate waste have led to significant quantities of solid waste accumulation at plant sites (Etim et al., 2021).

Waste Recycling

Waste recycling refers to the process of converting waste materials into reusable products to prevent waste accumulation, conserve resources, and minimize environmental impact. In the context of cement production, waste recycling entails reusing by-products and industrial residues; such as cement kiln dust, fly ash, slag, construction and demolition waste, and thermoset plastics; as alternative raw materials or fuels within the manufacturing process.

For Nigerian cement companies, integrating recycling into production systems not only offers a path toward sustainability but also presents opportunities for significant reductions in production and waste management costs. This discussion explores the concept of waste recycling, its relevance to cement manufacturing, and its critical implications for the current study, which evaluates how recycling practices influence production costs in Nigeria's cement industry.

Cement Waste Recycling Methods

The adoption of efficient recycling methods for cement waste is a cornerstone of sustainable cement manufacturing. In the context of Nigerian cement companies, exploring and implementing practical cement waste recycling strategies is critical not only for minimizing environmental degradation but also for reducing operational and production costs. Cement waste recycling encompasses a broad spectrum of strategies, ranging from the reuse of industrial by-products and demolition waste to advanced reprocessing techniques that restore the functionality of hydrated cement.

Cost Components in Cement Production

Cement production is a capital-intensive process characterized by high operational expenditures, which are influenced by multiple internal and external variables. Understanding the composition of these costs is essential for analyzing how interventions such as cement waste recycling could improve production efficiency and financial performance. In Nigeria, the cement manufacturing industry has undergone significant expansion, but it continues to grapple with high production costs stemming from energy consumption, raw materials, logistics, labor, regulatory burdens, and financial expenses. This section discusses the major cost components in cement production, linking each to the objectives of the current study which evaluates how cement waste recycling might reduce overall production costs in Nigeria.

Environmental Benefits of Cement Waste Recycling

Cement waste recycling plays a vital role in the global effort to mitigate environmental degradation associated with industrial processes. Cement manufacturing is widely recognized as a major contributor to environmental pollution, particularly in the form of greenhouse gas (GHG) emissions, resource depletion, and land degradation due to mining activities. In Nigeria, where rapid urbanization and infrastructure development are driving high demand for cement, these issues are especially pronounced. This discussion explores the environmental benefits of cement waste recycling in relation to the current study, which investigates how recycling practices impact production costs in Nigerian cement companies. It focuses on three major environmental outcomes: emission reduction, resource conservation, and waste minimization.

Theoretical Framework

The theoretical framework anchors this study within established academic perspectives that explain the dynamics of resource utilization, sustainability, and organizational adaptation in industrial processes. Specifically, the framework draws upon the Resource-Based View (RBV) Theory by Birger Wernerfelt in 1984.

Resource-Based View (RBV) Theory

The Resource-Based View (RBV) theory, first articulated by Birger Wernerfelt in 1984 and further developed by Barney (1991), serves as a strategic framework for understanding how firms achieve and sustain competitive advantage through the effective utilization of internal resources. According to RBV, resources that are valuable, rare, inimitable, and non-substitutable (VRIN) can enable firms to outperform competitors by enhancing productivity, reducing costs, or fostering innovation. In the context of cement manufacturing in Nigeria, the application of RBV provides a compelling theoretical foundation for evaluating cement waste recycling as a strategic internal resource capable of improving production efficiency and cost-effectiveness.

Cement waste comprising rejected cement, spillage, expired raw materials, and other production residues, is typically viewed as a liability. However, within the RBV framework, such waste can be re-conceptualized as a potentially valuable internal asset when subjected to appropriate recycling technologies. If managed strategically, recycled cement waste can substitute for a portion of virgin raw materials, thereby reducing procurement costs and enhancing cost efficiency; key determinants of firm competitiveness in a resource-intensive sector like cement manufacturing (Aliu et al., 2025).

Furthermore, RBV supports the notion that competitive advantage stems not only from resource possession but also from how resources are managed and integrated into organizational routines. In this regard, recycling processes embedded in production workflows rather than externally outsourced offer firms greater control, adaptability, and innovation potential. Such integration transforms waste recycling into a core operational strength, aligning with RBV's emphasis on embedded capabilities.

Empirical Review of Related Studies

Enengel, Viczek, and Sarc (2023), in a study "Determining the Recycled Content in Cement: A Study of Austrian Cement Plants", aimed to quantify the use of secondary raw materials in cement production and evaluate their impact on material efficiency. The study employed a case study methodology focused on two large-scale Austrian cement plants. Data collection involved analyzing mass and chemical flow of raw materials, with emphasis on determining the percentage of recycled content in final cement products. The employed method compared results obtained through mass-based calculations and chemical component analyses. The findings showed that recycled materials; primarily derived from industrial by-products and construction waste, constituted up to 38.7% of the total input materials. This substitution directly reduced the demand for virgin inputs such as limestone and clay, leading to measurable cost reductions.

Škondrić et al. (2025) carried out a study titled "Sustainable Lightweight Concrete Designed with Modified Solidified Wastewater Sludge as Partial Replacement of Cement." The authors investigated the feasibility of substituting cement with modified sludge to reduce raw material use and promote sustainable construction. The study aimed to assess both technical performance and public perception. The authors utilized a sample of four mortar mixtures in Serbia where cement was partially replaced (up to 20%) with aluminum oxide and magnesium silicate hydrate-enhanced sludge. The experimental method included tests for compressive strength, water permeability, and frost

resistance, along with a sociological survey on public acceptance. Findings revealed that a 20% replacement rate reduced water permeability by 33.3% and lowered compressive strength by only 7.6%. This result demonstrated minimal compromise in structural integrity while significantly cutting down on cement use.

Kirgiz et al. (2025), carried out a study titled "Waste marble sludge and calcined clay brick powders in conventional cement farina production for cleaner built environment." The authors addressed the escalating disposal costs associated with industrial byproducts from marble and brick manufacturing. The study applied experimental approach to evaluate the viability of using these wastes as substitutes for cement and clinker in cement production. The researchers prepared 24 binder combinations using varying proportions (0%, 6%, 10%, 20%, 21%, and 35%) of marble and brick powders. Standard mortar tests were performed on hardened samples to assess properties like water permeability, density, and strength. Microstructural analyses, including X-ray fluorescence and scanning electron microscopy, were used to evaluate material composition and behavior. The study revealed that the total oxides content in both wastes exceeded the thresholds for pozzolanic activity, with brick powder demonstrating significantly higher compressive and flexural strength contributions. The replacement reduced reliance on traditional raw materials and, crucially, diverted waste from disposal channels, thereby mitigating disposal costs. The authors concluded that marble sludge and brick powders not only enhanced concrete durability but also served as cost-effective, sustainable alternatives, reducing both environmental impact and waste disposal expenses in cement manufacturing.

Elnaggar, Ahmed, and Abbas (2023), in a paper titled "Recycling of bypass cement kiln dust in the production of eco-friendly roof tiles," investigated the dual objectives of reducing waste disposal costs and creating cost-efficient building materials. Conducted in an industrial setting, this experimental study focused on incorporating bypass cement kiln dust (BCKD); a waste byproduct of the cement kiln system-into roof tile production. The researchers substituted clay with BCKD at various levels (5–25%) and subjected samples to comprehensive physical tests. Using a quantitative research design, they assessed raw materials via XRD and XRF, and conducted firing tests at 1000°C, 1100°C, and 1150°C. Sample dimensions were standardized at 150 × 30 × 25 mm and compressed under 10 MPa before drying and firing. The results indicated that tiles with 8% and 12% BCKD met ASTM C1167 standards, with favorable water absorption (14%) and breaking strength (~2700 N). Moreover, the lower recommended firing temperature of 1100°C led to cost savings in energy use. The findings confirmed that integrating BCKD not only diverted waste from landfills but also reduced waste management expenses and production costs.

Akbar and Liew (2020), carried out a study titled "Assessing recycling potential of carbon fiber reinforced plastic waste in production of eco-efficient cement-based materials." The study explored the environmental and cost-related benefits of incorporating recycled carbon fibers (rCFs) into cement composites. The research addressed the critical issue of CFRP waste disposal in China, especially from the aeronautical and wind energy sectors, which is projected to generate up to 97,000 tons of landfill-bound waste by 2044. Utilizing an experimental quantitative research design, the study assessed the mechanical properties and environmental impact of cement composites reinforced with 1% rCFs by volume, while also replacing 10% of cement with silica fume. Analysis involved tensile and fracture tests, along with life cycle assessment tools for evaluating environmental performance. The results

demonstrated that the incorporation of rCFs significantly enhanced the mechanical performance of cement composites; raising elastic modulus by 57%, splitting tensile strength by 188%, and fracture toughness by 325%. Furthermore, the global warming potential of the modified mix decreased by 13.69%, and energy consumption dropped by 222%, translating into a 70% reduction in material cost when rCFs replaced virgin carbon fibers. Conducted at the City University of Hong Kong, the study concluded that recycling CFRP waste into cement products could meaningfully reduce waste disposal costs and carbon emissions, while enhancing material efficiency and sustainability in cement manufacturing.

Gap in Empirical Review

Existing empirical studies have extensively explored the technical, environmental, and economic benefits of recycling various waste materials into cement-based products. Nevertheless, a critical research gap remains regarding the comprehensive, industry-level evaluation of cement waste recycling and its cost implications within the Nigerian cement manufacturing sector. Most reviewed studies, such as those by Chen et al. (2022), Oh et al. (2021), and Luo et al. (2024), emphasized laboratory experiments and pilot-scale applications involving alternative raw materials or performance metrics. These studies focused predominantly on technical feasibility and environmental gains, often neglecting full-scale industrial implementation or cost-effectiveness in real production environments.

Furthermore, Nigerian-based research, such as that by Olawale et al. (2022) and Etim et al. (2021), highlighted the low adoption of recycling practices within cement-related operations. However, these studies largely underscored infrastructural, environmental, or health aspects, without quantifying how recycling affects core production cost components such as raw material procurement, waste disposal expenses, or energy usage. Similarly, broader assessments like that of Ogunseye et al. (2024) and Ezeudu et al. (2021) addressed systemic recycling barriers within Nigeria's industrial landscape but do not provide empirical insight into how these challenges intersect with cost structures in cement manufacturing.

Methodology

Research Design

This study adopted a descriptive survey design to systematically collect and analyze data on the extent, effects, and impact of cement waste recycling in Nigerian cement manufacturing companies. This design is appropriate for obtaining factual information, describing current practices, and identifying patterns related to recycling and cost structures (Creswell & Creswell, 2017).

Area of Study

The area of this study was Nigeria. The country is in West Africa with an approximate land area of 923,769 square kilometers. It is located between latitudes 4° and 14° North and longitudes 3° and 15° East. Nigeria is bordered by Cameroon to the east, Benin to the west, Niger to the north, and the Gulf of Guinea to the south. Nigeria is

recognized as the largest producer of cement in sub-Saharan Africa, with an annual production capacity exceeding 50 million metric tonnes as of 2022 (National Bureau of Statistics [NBS], 2022).

Source of Data

The primary source of data for this study is first-hand information collected directly from selected respondents within cement manufacturing companies located in Kogi, Cross River, and Edo States.

Population of the Study

This total population of 610 was obtained through preliminary on-sight research conducted by the researcher and the distribution is as shown in Table 1.

Table 1: Distribution of the Population of the study

S/N	Construction Company	Population of stakeholders
1	Dangote Cement Plc	229
2	Lafarge Africa Plc	198
3	BUA Cement Plc	183
Total		610

Source: Field data obtained by the researcher (2025)

Determination of Sample Size

Given the total population of 610 stakeholders, Krejcie and Morgan's formula (1970) is a most suitable method for determining the sample size. This method is particularly appropriate for a finite population like this. Its suitability lies in its ability to account for the limited size of the population, ensuring that the sample size is neither excessively large nor too small. Additionally, Krejcie and Morgan's formula guarantees that the sample size is statistically adequate to allow for generalization of the findings to the entire population of engineers. This evidently helps to minimize the risk of sampling error. The formula is presented in equation 1.

$$n = \frac{N \times \chi^2 \times P \times (1 - P)}{(d^2 \times (N - 1)) + (\chi^2 \times P \times (1 - P))}$$

where:

N = the population size (610 in this case).

χ^2 = the chi-square value for 1 degree of freedom at the desired confidence level (typically 3.841 for a 95% confidence level).

P = the population proportion (assumed to be 0.5 for maximum sample size).

d = the degree of accuracy expressed as a proportion (the margin of error, typically 0.05 for a 95% confidence level).

Using the Krejcie and Morgan's formula the sample size of the study at 95% confidence level is thus calculated:

$$n = \frac{610 \times 3.841 \times 0.5 \times (1 - 0.5)}{(0.05^2 \times (610 - 1)) + (3.841 \times 0.5(1 - 0.5))}$$

$$n = \frac{585.7525}{2.4828} = 236$$

Thus, using Krejcie and Morgan's formula, the calculated sample size for the study is approximately 236 participants.

Sampling Technique

This study employs a stratified random sampling technique to ensure representative sampling across the three (3) cement manufacturing companies. Thus, the total population of 610 was stratified into three distinct groups, and a sample size of 236 was proportionally allocated across these strata. The allocation was calculated based on each stratum's proportion in the total population, using Bourley's formula:

$$n_h = \frac{n_o \times N_h}{N} \quad (3.2)$$

where

n_h = sample size of stratum h

n_o = sample size of the study

N_h = the population size for stratum

N = the total population

Table 2: Sample Proportion allocation to the three cement manufacturing companies

S/N	Construction company	Population of stakeholder	Proportion allocation n_h
1	Dangote Cement Plc	229	89
2	Lafarge Africa Plc	198	77
3	BUA Cement Plc	183	70
	Total	610	236

This stratification ensures that each company is proportionally represented according to its size in the population. Expert sampling was applied within each stratum to select the designated number of participants. This approach, combining stratification with expert selection, improves the accuracy of population estimates and reduces sampling error.

Instrument of Data Collection

The primary instrument for data collection in this study is a structured questionnaire, designed to address the three research objectives effectively. This instrument is particularly suitable for the descriptive survey design adopted for this research. The structured questionnaire is carefully crafted to ensure comprehensive coverage of the research objectives while maintaining clarity and ease of response for participants.

Validity of the Instrument

Ensuring the validity of the structured questionnaire is crucial for accurately measuring the intended variables and generating data that truly aligns with the research objectives. To achieve this, the questionnaire underwent content validity assessment by three experts from the Department of Engineering Management at ESUT Business School, Enugu State University of Science and Technology, Enugu, Nigeria.

Reliability of Instrument

The reliability index for the four clusters were computed through the response of a trial test conducted on a sample of 20 experts from cement companies not selected in the present study. For the three clusters, the results were computed to be 0.79, 0.83 and 0.81 respectively. Thus, the instrument yielded a cumulative reliability index of 0.81. This reliability index is deemed accepted as it is above the benchmark of 0.7.

Method of Data Analysis

Descriptive statistics was used to summarize the data, including percentage, mean, and standard deviation. For inferential statistics, a one-sample two-way t-test was conducted to test the hypotheses and examine the relationships between variables. The data analysis was conducted using SPSS and Microsoft office Excel.

Data Presentaion, Analysis and Discussion of Findings

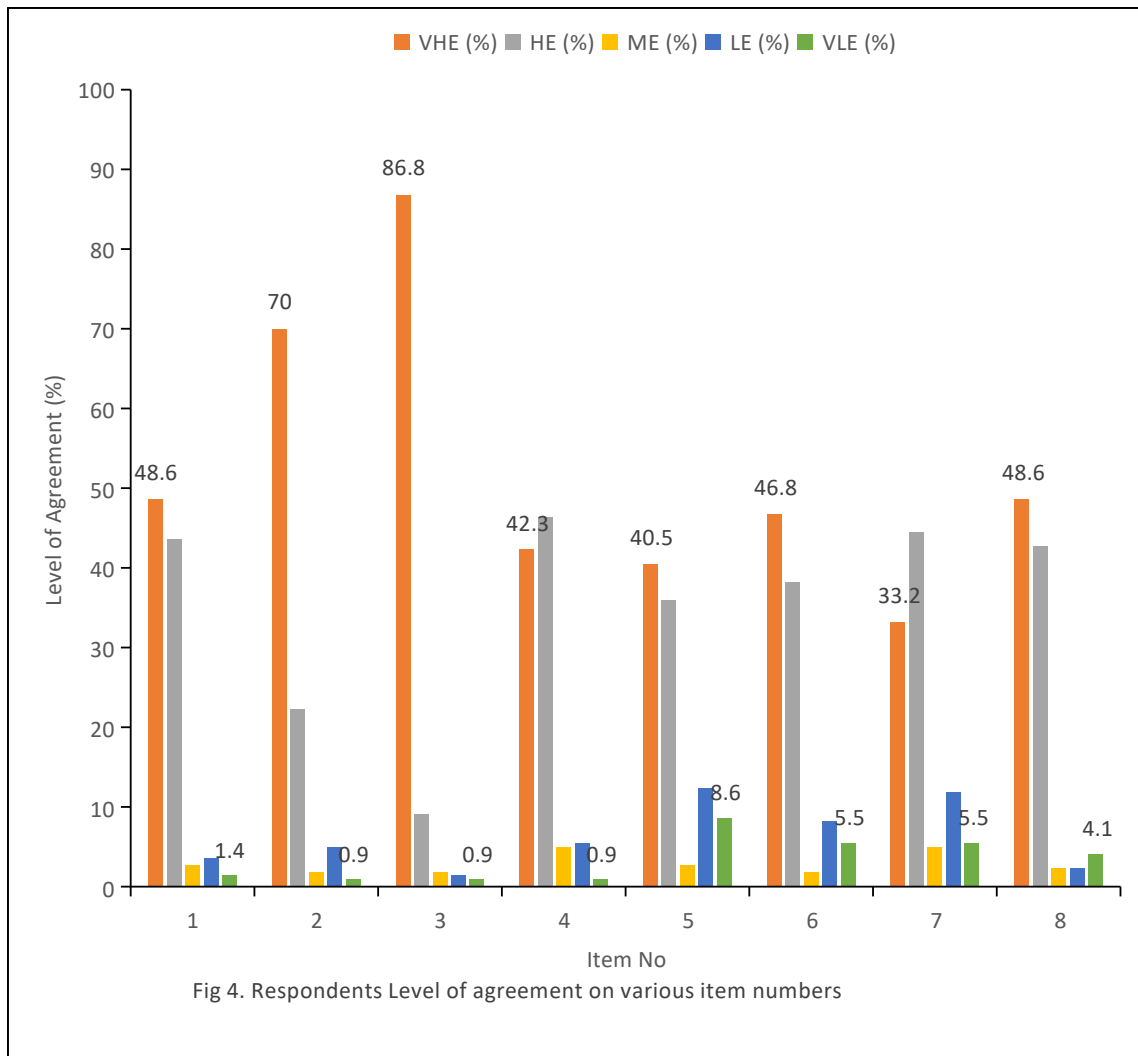
This SECTION presents data obtained by the researcher and the analysis of the data, and subsequent interpretation of the results of the analysis. Against this backdrop, this SECTION outlines four sections. The first Section focuses on the presentation of data obtained in relation to each of the three research questions. The second section centres on the analysis of the data obtained using statistical tools. The third section is concerned with the test of hypotheses, while the last section focuses on the discussion of the results obtained from the analyses.

Data presentation

Statistical Analysis of Research Question One

Table 3: Descriptive statistical analysis on the extent to which cement waste recycling are implemented in Nigeria cement manufacturing companies.

S/N	Item	VHE (%)	HE (%)	ME (%)	LE (%)	VLE (%)	Mean	Std.
1	Cement waste recycling is included in the company's routine production activities.	107 (48.6%)	96 (43.6%)	6 (2.7%)	8 (3.6%)	3 (1.4%)	4.35	0.82
2	Machinery or equipment for recycling cement waste is available on-site.	154 (70.0%)	49 (22.3%)	4 (1.8%)	11 (5.0%)	2 (0.9%)	4.55	0.83
3	Specific policies or internal guidelines exist for managing cement production waste.	191 (86.8%)	20 (9.1%)	4 (1.8%)	3 (1.4%)	2 (0.9%)	4.80	0.63
4	Waste cement materials are sorted and prepared for recycling rather than disposal.	93 (42.3%)	102 (46.4%)	11 (5.0%)	12 (5.5%)	2 (0.9%)	4.24	0.85
5	Training programs on cement waste recycling are provided to operational staff.	89 (40.5%)	79 (35.9%)	6 (2.7%)	27 (12.3%)	19 (8.6%)	3.87	1.30
6	A designated unit or team oversees the recycling of cement-related waste.	103 (46.8%)	84 (38.2%)	4 (1.8%)	18 (8.2%)	11 (5.0%)	4.14	1.12
7	Recycling of cement kiln dust and other by-products is actively practiced.	73 (33.2%)	98 (44.5%)	11 (5.0%)	26 (11.8%)	12 (5.5%)	3.88	1.16
8	Waste generated during cement packaging and storage is recycled internally.	107 (48.6%)	94 (42.7%)	5 (2.3%)	5 (2.3%)	9 (4.1%)	4.30	0.94
Grand mean/ Standard deviation							4.27	0.98



The descriptive analysis presented in Table 3 reveals significant insights into the level of implementation of cement waste recycling in Nigerian cement manufacturing companies. The analysis uses mean scores, standard deviation, and percentage responses to evaluate the degree of adoption across various operational indicators. These results are visually reinforced in Figure 4, which plots the distribution of mean values across the items.

The first indicator, which examines the inclusion of cement waste recycling in routine production activities, recorded a mean of 4.35 and a standard deviation of 0.82. This high mean, supported by a cumulative 92.2% agreement rate (Very High and High Extent), indicates widespread integration of recycling into daily operations, with relatively low variability among responses. Availability of machinery or equipment for recycling cement waste showed the second-highest implementation level with a mean of 4.55 and a standard deviation of 0.83. A total of 92.3% of respondents agreed to a high or very high extent, suggesting significant investment in the infrastructural tools necessary for recycling across the surveyed companies.

The existence of specific internal policies and guidelines was the highest-rated item, with a mean of 4.80 and a notably low standard deviation of 0.63. The strong consensus, evidenced by 95.9% agreement, implies a clear institutional commitment to formalizing recycling practices, which is a critical enabler for consistent

implementation. Sorting and preparation of waste cement materials for recycling yielded a mean of 4.24 and a standard deviation of 0.85. This result, with a combined 88.7% agreement, suggests that recycling is operationally embedded at the material-handling stage, although slightly less uniformly than policy-based indicators.

Training programs for operational staff received a comparatively lower mean of 3.87 and a standard deviation of 1.30, reflecting more varied responses and a lower agreement level (76.4%). This suggests that while recycling is structurally supported, workforce development through regular training may be less prioritized or inconsistently implemented. Oversight of recycling by designated units was rated with a mean of 4.14 and a standard deviation of 1.12. With 85% of respondents indicating high or very high extent, this reflects a fairly strong structural allocation of responsibilities, though some variability in implementation is observed.

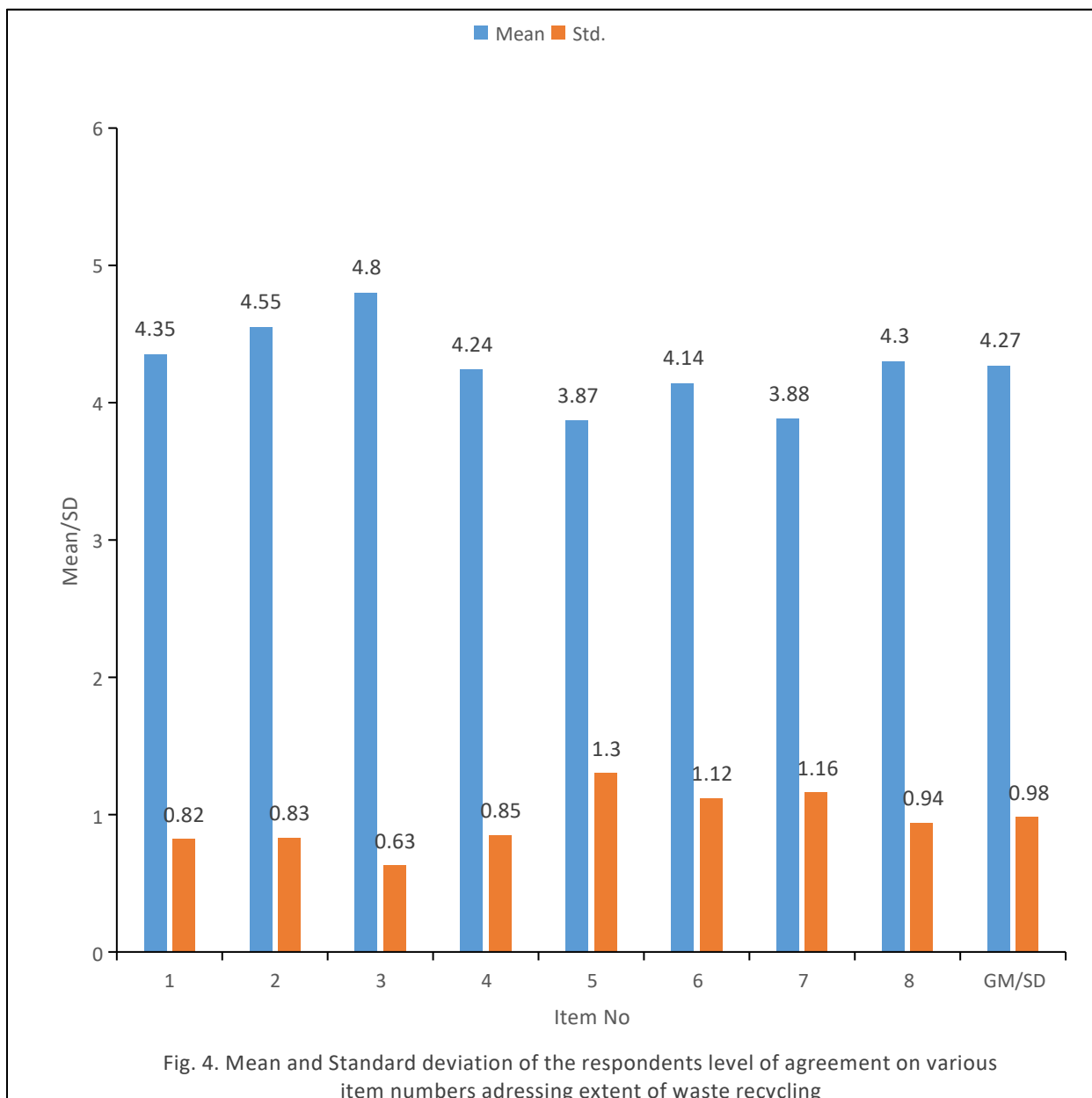


Figure 4: The Extent of cement waste recycling in Nigeria

Recycling of cement kiln dust and by-products scored a mean of 3.88 with a standard deviation of 1.16. The relatively modest 77.7% agreement and higher standard deviation suggest that this specific practice may not be uniformly implemented across all facilities, potentially due to technical limitations or cost considerations. Internal recycling of packaging and storage waste achieved a mean of 4.30 and a standard deviation of 0.94, with a high 91.3% agreement level. This reflects consistent recycling practices for post-production waste, indicating a strong commitment to minimizing waste along the entire production chain.

The overall grand mean of 4.27 and standard deviation of 0.98 confirms a generally high level of cement waste recycling implementation across the sampled companies. Although some dimensions; particularly those related to training and specialized waste streams; still exhibit moderate variability. As illustrated in Figure 4, the mean scores underscore that while structural and policy elements of recycling are well-established, further efforts are needed to improve operational consistency and staff capacity building.

Statistical Analysis of Research Question Two

Table 4: Descriptive statistical analysis on the effect of cement waste recycling on the cost of raw materials used in cement production.

S/N	Item							
1	Recycling cement waste contributes to a measurable reduction in raw material costs.	99 (45.0%)	83 (37.7%)	14 (6.4%)	6 (2.7%)	18 (8.2%)	4.09	1.17
2	The use of recycled cement materials decreases the volume of virgin raw materials used.	186 (84.5%)	29 (13.2%)	5 (2.3%)	0 (0.0%)	0 (0.0%)	4.82	0.44
3	Recycling cement kiln dust reduces the demand for imported additives.	190 (86.4%)	24 (10.9%)	4 (1.8%)	2 (0.9%)	0 (0.0%)	4.83	0.48
4	Incorporating recycled cement waste improves cost efficiency in sourcing raw materials.	201 (91.4%)	19 (8.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4.91	0.28
5	Recycled waste materials are viable substitutes for traditional cement inputs.	97 (44.1%)	63 (28.6%)	13 (5.9%)	26 (11.8%)	21 (9.5%)	3.86	1.35
6	The cost of procuring raw materials is lower when cement waste recycling is practiced.	87 (39.5%)	73 (33.2%)	13 (5.9%)	26 (11.8%)	21 (9.5%)	3.81	1.33
7	Recycling practices have led to a noticeable reduction in limestone and clay usage.	87 (39.5%)	91 (41.4%)	7 (3.2%)	14 (6.4%)	21 (9.5%)	3.95	1.24

S/N	Item							
8	Investment in recycling contributes to long-term savings on raw material procurement.	119 (54.1%)	91 (41.4%)	5 (2.3%)	4 (1.8%)	1 (0.5%)	4.47	0.68
Grand mean/ Standard deviation							4.34	0.97

The descriptive analysis presented in Table 4 evaluates respondents' perceptions of how cement waste recycling affects the cost of raw materials in cement production. The results are analyzed based on mean scores, standard deviations, and percentage distributions. The insights presented are further supported by Figure 4, which graphically illustrates the distribution of mean values across all items.

The first item assessing whether recycling leads to measurable reductions in raw material costs recorded a mean of 4.09 and a standard deviation of 1.17. Approximately 82.7% of respondents expressed agreement (SA and A), indicating broad support for the cost-saving potential of recycling. However, the relatively high standard deviation suggests some variation in experience across companies or roles. The second item, evaluating the extent to which recycled cement materials reduce reliance on virgin raw materials, showed exceptionally high consensus. With a mean of 4.82 and a low standard deviation of 0.44, and 97.7% of respondents agreeing or strongly agreeing, this result confirms the clear effectiveness of recycled inputs in replacing natural materials in production processes.

A similar trend is evident in the third item, where 97.3% agreed that recycling cement kiln dust reduces the demand for imported additives. This item recorded a mean of 4.83 and a standard deviation of 0.48, affirming a strong alignment among respondents and minimal dispersion in responses, indicative of uniform implementation or awareness of kiln dust utilization. The highest consensus was observed in the fourth item, which reported a mean of 4.91 and the lowest standard deviation of 0.28. All respondents either strongly agreed or agreed that incorporating recycled cement waste enhances cost efficiency in sourcing raw materials. This unanimous response reinforces the economic relevance of recycling in raw material management and reflects well-established practices in the surveyed companies.

By contrast, the fifth item, addressing the perceived viability of recycled materials as substitutes for traditional inputs, received a lower mean of 3.86 and the highest standard deviation of 1.35. Although 72.7% of respondents agreed, the high variability indicates differences in confidence levels, likely due to inconsistent performance outcomes or limited access to certain recycling technologies. The sixth item also presented a moderate mean of 3.81 and a standard deviation of 1.33. Despite a majority agreement of 72.7%, the spread of responses reflects possible disparities in cost accounting practices or differing levels of maturity in recycling implementation across companies. The seventh item, focusing on reductions in limestone and clay usage, had a mean of 3.95 and a standard deviation of 1.24, with 80.9% agreement. This result supports the argument that recycling leads to material conservation, though variability remains across operational contexts. Finally, the eighth item; on long-term savings from recycling investments-achieved a strong mean of 4.47 and a low standard deviation of 0.68, with 95.5%

agreement. This underscores a widely shared belief in the strategic economic value of recycling beyond immediate cost reductions.

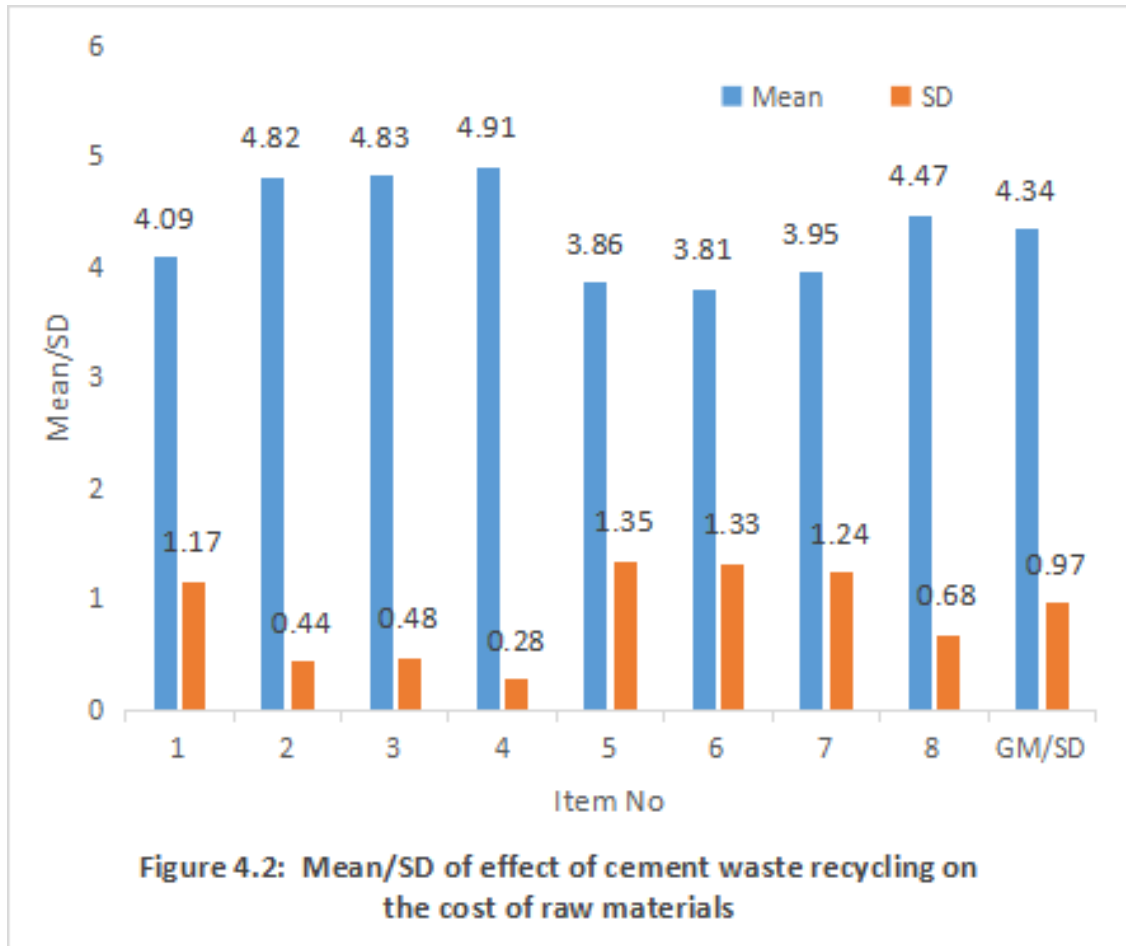


Figure 4.2: Mean/Standard Deviation of effect of cement waste recycling on the cost of raw materials

The grand mean of 4.34 and a standard deviation of 0.97 collectively affirm a high level of agreement that cement waste recycling positively influences raw material cost reduction. Figure 4.2 clearly illustrates this pattern, with all mean values positioned above the midpoint of the scale, reflecting strong consensus across most indicators.

Test of Hypotheses

Evaluation of the First Null Hypothesis

Table 5: One sample t-test on the first null hypothesis

Parameters	Description
Sample mean	4.27
Test value (μ_0)	3.00

Parameters	Description
Standard deviation (s)	0.98
Degree of Freedom	7
Standard error (SE)	$\frac{s}{\sqrt{n}} = 0.35$
t-statistic Calculation	$\frac{\bar{x} - \mu_0}{SE} = 3.62$
Degree of Freedom	7
Critical t-value (Two-tailed), $\alpha = 0.05$	± 2.365
Comparison	Calculated t-statistic (3.62) > Critical value (2.365)
Conclusion	Reject H_{01} : There is enough evidence to conclude that there is significant implementation of cement waste recycling practices in Nigerian cement manufacturing companies in Nigeria.

Table 5 presents results of the one-sample t-test conducted to assess the first null hypothesis. The null hypothesis posits that there is no significant implementation of cement waste recycling practices in Nigerian cement manufacturing companies. The analysis provided compelling evidence to the contrary. The sample yielded a mean score of 4.27, significantly higher than the test value of 3.00, which represents a neutral stance on the Likert scale. This difference, combined with a standard deviation of 0.98 and a computed standard error of 0.35, resulted in a t-statistic of 3.62. When compared against the two-tailed critical t-value of ± 2.365 at 7 degrees of freedom and a 0.05 significance level, the calculated t-value clearly exceeds the critical threshold.

This statistical outcome leads to the rejection of the null hypothesis, affirming that the implementation of cement waste recycling practices is statistically significant among Nigerian cement manufacturing firms. The high sample mean not only reflects a strong inclination toward the adoption of recycling practices but also aligns with earlier descriptive findings that highlighted widespread agreement on the cost and operational benefits of such initiatives. The reliability of this conclusion is reinforced by the relatively low standard error, suggesting that the observed mean is a precise estimate of the population mean.

Furthermore, the magnitude of the t-statistic underscores the practical significance of the findings, indicating that cement manufacturing companies are not merely adopting recycling practices in isolated cases but are doing so to a meaningful extent. This could be attributed to increasing awareness of environmental regulations, economic incentives, or corporate sustainability goals that prioritize resource efficiency. Thus, the analysis substantiates the assertion that cement waste recycling is not only present but significantly embedded within the operational strategies of Nigerian cement firm

Evaluation of the Second Null Hypothesis

Table 6: One-Sample t-test on the second null hypothesis

Parameters	Description
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Sample mean	4.34
Test value (μ_0)	3.00
Standard deviation (s)	0.98
Degree of Freedom	7
Standard error (SE)	$\frac{s}{\sqrt{n}} = 0.34$
t-statistic Calculation	$\frac{\bar{x} - \mu_0}{SE} = 3.94$
Degree of Freedom	7
Critical t-value (Two-tailed), $\alpha = 0.05$	± 2.365
Comparison	Calculated t-statistic (3.94) > Critical value (2.365)
Conclusion	Reject H_{02} : There is enough evidence to conclude that cement waste recycling has significant effect on the cost of raw materials used in cement production.

The one-sample t-test conducted to evaluate the second null hypothesis (H_{02}), which posits that cement waste recycling has no significant effect on the cost of raw materials used in cement production, provides statistically compelling evidence to reject this assumption. As shown in Figure 2, the test was based on a sample mean of 4.34, drawn from aggregated responses to eight questionnaire items measuring the impact of recycling on raw material cost reduction. The test value, representing a neutral position on the five-point Likert scale, was set at 3.00.

With a standard deviation of 0.98 and a calculated standard error of 0.34, the resulting t-statistic was computed at 3.94. This value exceeds the critical t-value of ± 2.365 at a 0.05 significance level for 7 degrees of freedom in a two-tailed test. This comparison; where the computed t-statistic is substantially greater than the critical threshold indicates that the observed difference between the sample mean and the test value is statistically significant and unlikely due to random variation.

Therefore, the null hypothesis is rejected in favor of the alternative hypothesis, leading to the conclusion that cement waste recycling has a significant effect on reducing the cost of raw materials used in cement production. This finding aligns with the descriptive analysis presented earlier, which showed high levels of agreement among respondents regarding the cost-saving benefits of recycling practices. The statistical outcome reinforces the notion that recycling not only contributes to environmental sustainability but also serves as a practical economic strategy for optimizing raw material usage in Nigeria’s cement manufacturing sector. As such, the integration of recycling into production processes can be considered both a financially and operationally advantageous practice.

Discussion of Results

The analysis of responses related to the first research question indicates a substantial level of adoption. This outcome suggests that recycling practices are not only acknowledged but are being operationalized across various dimensions of cement production. These findings align closely with those of Oh et al. (2021). The authors demonstrated the technical feasibility and potential for recycling concrete waste into new cementitious materials.

The study suggested that the foundation for systematic recycling practices exists even if not uniformly scaled. Similarly, the high degree of policy presence and operational integration found in this study echoes the findings of Chen et al. (2022), who observed moderate but growing implementation of recycling plastic waste in cement mortar. This finding reinforces the view that practical applications of recycling are gaining momentum within the sector.

In contrast, the study diverges from findings by Etim et al. (2021) and Ezeudu et al. (2021), both of whom reported limited institutional recycling due to inadequate infrastructure and poor regulatory enforcement. The present research indicates notable internal policy frameworks and operational teams dedicated to recycling. The gap identified by these earlier studies may reflect broader national inconsistencies rather than sector-specific performance. This distinction underscores the potential of the cement industry as a frontrunner in waste recycling within Nigeria, even as systemic challenges persist elsewhere.

Summary of Findings, Conclusion and Recommendations

Summary of Findings

- i. The extent of implementation of cement waste recycling in Nigerian cement manufacturing companies was found to be substantial, with an overall mean of 4.27, indicating widespread adoption of recycling practices.
- ii. Recycling practices were reported to significantly reduce the cost of raw materials used in cement production, reflected in a high overall mean of 4.34, suggesting notable material efficiency and cost-saving benefits.

Conclusion

This study evaluated the impact of cement waste recycling on production cost in Nigerian cement manufacturing companies by examining its implementation, influence on raw material cost, and effect on waste disposal expenses. The findings revealed that cement waste recycling is not only acknowledged but actively integrated into the operational frameworks of many Nigerian cement firms. Evidence of policy structures, designated recycling units, and the use of on-site equipment affirms the extent to which recycling practices have become embedded in daily production activities. This level of implementation suggests a strategic shift toward sustainability and resource efficiency within the industry.

Recommendations

Based on the findings of this study, it is recommended that:

- i. Cement manufacturing companies should deepen the integration of waste recycling into their routine operations by investing in specialized equipment and dedicated recycling units to enhance implementation.
- ii. Industry stakeholders should adopt recycling technologies that enable the reuse of cement-related waste as substitutes for raw materials to reduce production costs and conserve natural resources.

Contribution to Knowledge

The study contributes to existing knowledge by providing empirical evidence on the practical implementation and economic impact of cement waste recycling within the Nigerian cement industry. It advances the understanding of how recycling practices not only support environmental sustainability but also drive cost efficiency in raw material sourcing and waste disposal. By highlighting industry-specific adoption patterns, infrastructural readiness, and policy implications, the research offers a contextualized perspective on the viability of circular economy practices in developing economies. It serves as a reference point for policymakers, industry leaders, and researchers aiming to promote sustainable production frameworks in the construction materials sector.

Suggestion for Future Studies

Future studies could explore the long-term financial performance of cement companies that adopt large-scale recycling practices. Research should also examine the environmental impact of cement waste recycling on air and water quality in host communities. Additionally, comparative studies across different regions or countries could reveal best practices and implementation gaps in recycling within the cement industry.

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