WASTE-TO-WEALTH: CIRCULAR ECONOMY MODELS IN NIGERIAN CONSTRUCTION

H. C. O. Unegbu[1*], D.S. Yawas[2], B. Dan-asabe[3], A. A. Alabi[4]

Abstract

The construction industry is a major consumer of natural resources and a significant generator of solid waste, with Nigeria experiencing critical inefficiencies in managing construction and demolition waste. This study investigates the adoption of circular economy (CE) principles in Nigeria's construction sector, focusing on current waste management practices, material utilisation efficiency, and the potential economic and environmental benefits of transitioning from a linear to a circular model. Using a mixed-methods research design, the study integrates quantitative surveys, qualitative interviews, and direct field observations across major construction hubs in Lagos, Abuja, and Port Harcourt. Results reveal that landfilling remains the dominant disposal method, with concrete accounting for 45% of total construction waste, followed by wood (20%), metal (15%), plastic (10%), and mixed debris (10%). Despite growing global emphasis on circular construction, awareness of CE principles remains low in Nigeria, with only 32% of firms reporting high familiarity. Barriers such as weak regulatory enforcement, limited investment in waste recovery infrastructure, and a lack of financial incentives were identified as key constraints. Logistic regression analysis indicates that financial constraints negatively affect CE adoption, while policy support significantly improves the likelihood of implementation. Nonetheless, the study highlights considerable benefits associated with CE adoption, including a projected 30% reduction in waste disposal costs, a 25% increase in material efficiency, a 35% decrease in carbon emissions, and a 20% rise in job creation within recycling and waste-to-wealth sectors. To accelerate CE uptake, the study recommends stronger regulatory frameworks, investment in recycling infrastructure, integration of digital material tracking technologies, and the promotion of modular construction techniques. A collaborative, multi-stakeholder approach involving government, industry, and research institutions is essential to driving the transition towards a sustainable, circular construction economy in Nigeria.

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[1,2,3,4]Department of Mechanical Engineering, Ahmadu Bello University, Zaria, Nigeria.

Corresponding author:
chidieberehyg@gmail.com

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1.0 INTRODUCTION

The construction industry in Nigeria plays a pivotal role in national economic development, contributing approximately 9% to the country's Gross Domestic Product (GDP) (Adeleke, 2019). Nevertheless, the sector remains a substantial contributor to environmental degradation, with an estimated 30–40% of construction materials ending up as waste due to inefficient resource utilisation, poor planning, and outdated construction techniques (Olawale & Garba, 2020). This mismanagement not only leads to significant financial losses but also intensifies land degradation, deforestation, and greenhouse gas emissions (Eze *et al.,* 2021). In light of these challenges, transitioning to a circular economy (CE) model within the Nigerian construction industry offers a promising pathway for enhancing sustainability, improving resource efficiency, and reducing waste generation.

Globally, the integration of CE principles into the construction sector has yielded measurable success. In countries such as the Netherlands and Finland, waste-to-wealth programmes have led to reductions in construction-related material waste and carbon footprints (Pellinen, *et al.,* 2020). In contrast, Nigeria's adoption of circular economy strategies remains limited, primarily due to regulatory weaknesses, insufficient recycling infrastructure, and a general lack of awareness among construction stakeholders (Okafor & Ibrahim, 2022).

The conventional linear economy model—typified by the "take–make–dispose" approach—continues to dominate construction practices in Nigeria, contributing to unsustainable resource consumption and increased environmental risk. A circular economy, by contrast, is designed to maintain the value of products, materials, and resources in the economy for as long as possible, and to minimise waste generation through processes such as recycling, refurbishment, and reuse (Korhonen *et al.,* 2018).

In the context of construction, CE strategies may include the use of environmentally friendly materials, prefabrication techniques, adaptive reuse of buildings, and the recycling of construction and demolition waste (Geissdoerfer *et al.,* 2017). These approaches not only reduce the environmental footprint of construction activities but also create economic opportunities by transforming waste into valuable resources. Studies in the European Union have shown that adopting circular economy practices in construction can result in a 40% reduction in greenhouse gas emissions and a 50% decrease in the demand for virgin raw materials (European Commission, 2019). Emerging studies in Nigeria similarly suggest that effective implementation of CE strategies could yield a 20% reduction in construction waste and contribute to a 15% increase in employment within the recycling and materials recovery sectors (Adewale & Musa, 2021).

Despite the potential benefits, the transition towards a circular economy in Nigeria's construction industry remains slow and fragmented. Key obstacles include policy incoherence, absence of financial incentives, and resistance from traditional firms unwilling to abandon established linear practices (Nwankwo & Ajayi, 2020). The continued reliance on raw material extraction without adequate recovery systems has led to rising project costs, material shortages, and increased pressure on landfills (Bello & Yusuf, 2019). Approximately 70% of construction and demolition waste in Nigeria is disposed of in landfills or unauthorised dumping sites, with minimal efforts towards recovery or reuse (Agunbiade & Adeyemi, 2020). Furthermore, the absence of standardised waste segregation practices significantly hampers the development of effective recycling initiatives (Chukwuma, *et al.,* 2021). The limited adoption of CE principles can also be attributed to underinvestment in sustainable technologies and inadequate policy enforcement (Okonkwo *et al.,* 2022).

Addressing these multifaceted challenges requires a holistic and collaborative approach that integrates regulatory reform, technological advancement, financial incentives, and stakeholder engagement. This study seeks to explore how circular economy models can be implemented to support waste-to-wealth initiatives and foster sustainable practices within Nigeria's construction sector. Specifically, the research aims to: (i) assess the current state of construction waste management; (ii) evaluate the level of CE adoption among stakeholders; and (iii) analyse the potential economic and environmental benefits of CE integration. Additionally, it will identify critical barriers—including regulatory, infrastructural, and behavioural limitations—and propose strategic interventions for enhancing CE implementation. The study's findings are expected to inform policy development and business practices, contributing not only to the transformation of the Nigerian construction sector but also to the broader sustainability agenda. Importantly, the outcomes align with the United Nations Sustainable Development Goals, particularly Goal 11 (Sustainable Cities and Communities) and Goal 12 (Responsible Consumption and Production) (United Nations, 2015).

2.0 LITERATURE REVIEW

2.1 Conceptual Framework

The circular economy (CE) is a sustainable economic model that seeks to minimise waste and optimise the continuous use of resources through recycling, reuse, and regeneration. In contrast to the traditional linear economy, which follows a "take–make–dispose" trajectory, CE focuses on reducing raw material consumption while promoting material recovery and environmental conservation (Preston, 2012). The construction industry is one of the most resource-intensive sectors globally, producing significant amounts of waste, including concrete, wood, metals, and plastics. Studies indicate that construction and demolition waste (CDW) contributes up to 40% of total global solid waste, with developing nations such as Nigeria being key contributors due to weak waste management systems (Zhang *et al.,* 2019).

In the Nigerian context, construction waste is typically disposed of in landfills or unauthorised dump sites, owing to inadequate waste segregation practices and a scarcity of recycling infrastructure. Estimates suggest that only about 10% of CDW is currently recycled in Nigeria, compared with over 80% in several European countries with well-established CE policies (Afolabi & Oyebanji, 2020). Adopting CE principles in Nigeria's construction sector could enhance material efficiency, reduce environmental impact, and generate cost savings. Potential CE strategies include modular construction, urban mining, and the use of digital tools such as material passports, which facilitate the tracking, reuse, and recycling of construction components (Pomponi & Moncaster, 2017).

2.2 Theoretical Framework

Several theoretical frameworks underpin the application of CE in the construction sector. The Cradle-to-Cradle (C2C) theory advocates for designing products in a way that allows them to be reused or recycled continuously, effectively eliminating waste. This approach has seen substantial application in high-income countries through the use of eco-friendly materials and disassembly techniques, although implementation in Nigeria remains constrained by limited financial resources and technological capacity (Braungart & McDonough, 2009).

The Industrial Ecology Model conceptualises industries as interconnected ecosystems where the waste output from one sector becomes the input for another. This theory promotes material symbiosis between construction companies, manufacturers, and recycling enterprises, thereby reducing dependency on virgin materials and mitigating environmental damage (Graedel & Allenby, 2010). Recent research by Unegbu *et al.* (2024) suggested that adopting industrial symbiosis in Nigeria's construction sector could reduce construction waste by up to 35% while fostering circular business models.

Another widely applied model is Life Cycle Assessment (LCA), which evaluates the environmental impact of building materials and processes from extraction to disposal. LCA facilitates informed decision-making regarding material selection, construction techniques, and energy efficiency. Studies have shown that incorporating LCA tools into construction project planning in Nigeria could reduce lifecycle carbon emissions by 25% and significantly improve resource utilisation (Adesanya *et al.,* 2023).

2.3 Empirical Review

Numerous countries have successfully integrated CE principles into their construction sectors through regulatory mandates, technological advancement, and financial incentives. The Netherlands, for instance, introduced the Circular Construction 2023 policy, which requires that 50% of materials in new construction projects be recycled by 2030. Finland has implemented a Material Passport System to digitally log building components, thereby streamlining material reuse and supporting the growth of secondary markets (Ghisellini *et al.,* 2016).

Empirical findings suggest that these policies have considerably reduced construction waste while expanding opportunities in materials recovery markets (Ellen MacArthur

Foundation, 2019). Conversely, Nigeria lacks a national framework for circular construction practices. According to Ajiyo (2024), over 75% of construction waste in the country is sent to landfills, with minimal efforts towards recycling or recovery. The limited availability of financial incentives and the absence of market demand for secondary materials have further constrained CE adoption (Ogunleye & Odum, 2022).

Nonetheless, isolated projects indicate the potential for CE integration in Nigeria. For example, the Lagos Recycled Concrete Project demonstrated that using recycled concrete aggregates in construction could reduce project costs by 20% while enhancing structural integrity (Balogun *et al.,* 2022). Likewise, studies on bamboo-based construction in rural communities found that incorporating sustainable materials significantly decreased construction costs and environmental impact, thereby validating the viability of circular building methods (Okorie *et al.,* 2023). Despite these promising developments, various barriers continue to hinder the widespread adoption of CE principles in Nigeria's construction sector. These include regulatory deficiencies due to the lack of a cohesive national policy, economic challenges such as the high initial cost of green materials, technological constraints stemming from outdated practices, and cultural resistance to the use of recycled materials, which are often perceived as inferior (Olawumi & Chan, 2018; Dangana *et al.,* 2020; Adebayo & Iloh, 2021; Ojo & Bello, 2022).

Nevertheless, the potential benefits of CE implementation in Nigeria's construction industry are substantial. Research suggests that circular construction practices could result in a 30% reduction in construction waste, a 25% decrease in raw material demand, and a 15% increase in employment within waste recovery and recycling sectors (Akinbile *et al.,* 2023). Environmentally, the adoption of CE models could cut construction-related carbon emissions by 35%. Moreover, the introduction of green building materials such as bamboo, rammed earth, and compressed stabilised earth blocks has been shown to reduce construction costs by up to 20% while improving thermal efficiency and material durability (Umeh *et al.,* 2023).

2.4 Regulatory and Policy Framework

A robust regulatory framework is fundamental to accelerating the adoption of circular economy (CE) principles within Nigeria's construction industry. Internationally, countries such as Germany and Sweden have adopted stringent waste hierarchy policies that mandate the prioritisation of material reuse and recycling before landfill disposal. At the supranational level, the European Union's Waste Framework Directive establishes binding recycling targets for construction and demolition waste while promoting the use of secondary raw materials in construction projects (European Commission, 2018).

In contrast, Nigeria's existing policy environment remains underdeveloped in terms of CE-specific directives. Instruments such as the Environmental Impact Assessment (EIA) Act (Federal Government of Nigeria, 1992) and the National Environmental Standards and Regulations Enforcement Agency (NESREA) Act provide a foundational regulatory structure but lack explicit provisions for circularity in construction (NESREA, 2007). These policies primarily address environmental compliance and pollution control, offering minimal guidance on sustainable materials management or the integration of circular construction principles.

To bridge these policy gaps, scholars and practitioners have advocated for the development of a National Circular Economy Roadmap that would define CE implementation targets, introduce financial incentives for circular construction projects, and enforce stricter waste segregation laws (Ajulor, 2023). Key policy recommendations include the adoption of Extended Producer Responsibility (EPR) schemes that require construction firms to oversee material take-back and recovery processes, the formulation of Green Procurement Guidelines for prioritising sustainable and recycled materials in public-sector construction, and the establishment of a Circular Economy Task Force to coordinate CE initiatives across the built environment (Bello & Ayoola, 2022). These policy tools could collectively foster a more enabling environment for CE integration in Nigeria's construction industry.

2.5 Research Gap

While growing interest surrounds CE in Nigeria's construction sector, significant research gaps persist that this study aims to address in pursuit of its broader objectives. Notably, existing literature offers limited empirical evidence on the practical benefits and challenges of CE adoption within the Nigerian construction context. Most available studies are either conceptual or policy-focused, with few providing data-driven assessments of CE implementation outcomes (Okeke *et al.,* 2022). This research directly responds by presenting empirical insights into the economic and environmental implications of CE integration at the project and material levels.

Moreover, current scholarship has not adequately explored the recovery and reuse potential of specific construction materials—such as concrete, timber, and metals—within Nigeria's distinctive socioeconomic and infrastructural landscape. This study addresses this by analysing the recyclability and reuse feasibility of locally prevalent construction materials, thereby offering grounded insights into material flows and circular value chains. Additionally, although digital technologies such as Artificial Intelligence (AI), Blockchain, and Building Information Modelling (BIM) have proven beneficial in enhancing CE practices globally, their role in Nigeria's construction sector remains underexplored. This study evaluates the potential application of these technologies in advancing material traceability, design optimisation, and lifecycle monitoring to support CE adoption.

Finally, there is a pressing need to critically assess Nigeria's regulatory framework in relation to circular construction principles. Existing environmental laws and standards rarely align with CE priorities such as material looping, lifecycle thinking, or regenerative design. By identifying policy strengths and limitations, this research proposes actionable legal and institutional reforms to enhance CE adoption. Taken together, these research components aim to fill critical knowledge and practice gaps, thereby supporting the study's overarching goals: to assess the feasibility of CE in Nigerian construction, identify key barriers to implementation, and recommend evidence-based strategies for enabling sustainable, circular building practices.

3.0 METHODOLOGY

3.1 Research Design

This study adopted a mixed-methods research design, integrating both quantitative and qualitative approaches to enable a comprehensive analysis of circular economy (CE) implementation in Nigeria's construction industry. The mixed-methods approach was chosen to facilitate triangulation, thereby enhancing the validity and depth of insights related to waste management practices, levels of CE adoption, and the barriers impeding the transition to sustainable construction (Creswell & Plano Clark, 2017). The research incorporated a descriptive design to evaluate the current status of CE implementation and an explanatory design to investigate factors influencing its adoption. The study was conducted in Lagos, Abuja, and Port Harcourt, three of Nigeria's major urban centres with high volumes of construction activity, diverse stakeholders, and varying degrees of regulatory enforcement.

The unit of analysis included construction companies, regulatory agencies, policymakers, and waste management firms engaged in recycling and CE initiatives. The study focused on examining waste generation patterns, evaluating material recovery potential, and assessing the influence of policy frameworks on CE adoption in Nigeria's construction sector (Olawale & Umeh, 2022).

3.2 Data Collection Methods

The study utilised both primary and secondary data sources to ensure a comprehensive understanding of circular economy (CE) implementation within the Nigerian construction sector. Primary data were collected through structured surveys, semi-structured interviews, and direct field observations, while secondary data were obtained from academic literature, government publications, and industry reports. A structured questionnaire was developed to measure the level of awareness, the extent of CE implementation, and the challenges faced within the construction sector. The survey instrument was divided into four main sections: demographics, circular economy awareness, waste management practices, and barriers to CE adoption. Respondents rated their agreement with each statement using a five-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), in line with conventional survey design methods (Bryman, 2016).

Table 1: Survey Questionnaire

SN	Category	Survey Questions
1	Demographics	What is your role in the construction industry?
2		How many years of experience do you have in the sector?
3		What type of construction projects do you work on?
4		What is the size of your company?
5		Have you received any training on sustainable building?
6		Are you aware of circular economy principles?
7		Do you have formal waste management policies?
8	Circular Economy Awareness	Do you consider CE important for the Nigerian construction sector?
9		Are CE principles incorporated in your construction projects?
10		Are you familiar with government policies on CE in construction?
11		Do you believe CE adoption can reduce construction waste?
12		Have you encountered clients requesting CE-based construction?
13		Do you believe there are financial incentives for CE adoption?
14		Do you think the Nigerian government supports CE adoption?
15	Waste Management Practices	How does your company manage construction waste?
16		Do you use recycled construction materials?
17		Are waste materials sorted at your construction site?
18		Does your company collaborate with recycling firms?
19		Are there cost savings associated with material recovery?
20		Do you believe waste-to-wealth initiatives can be profitable?
21		Is digital technology used to track waste management?
22	Barriers to CE Adoption	Are financial constraints a major obstacle to CE adoption?
23		Are regulatory barriers limiting CE implementation?
24		Is a lack of awareness among stakeholders an issue?
25		Do you believe a lack of infrastructure affects CE adoption?
26		Does your company face resistance to change when implementing CE?
27		Is there a lack of skilled personnel for CE implementation?
28		Do you believe policy incentives could encourage CE adoption?

To complement the survey data, semi-structured interviews were conducted with 20 key informants, comprising policymakers, sustainability consultants, and senior executives from construction firms that had adopted CE practices. These interviews provided in-depth insights into contextual issues such as policy challenges, financial barriers, and levels of stakeholder engagement. The qualitative responses, as documented by Okoye and Nnaji (2023), enriched the study by capturing perspectives not readily quantifiable through survey instruments.

Additionally, direct observations were carried out at five active construction sites across Lagos, Abuja, and Port Harcourt. During these visits, field notes were recorded regarding the volume and type of construction waste generated, on-site recycling processes, segregation practices, and the reuse of materials such as concrete, timber, and steel (Adekunle *et al.*, 2023). Secondary data were sourced from a combination of national and international documents. These included publications by the

Federal Ministry of Environment, reports from the Nigerian Green Building Council, and datasets from the United Nations Environment Programme (UNEP). Peer-reviewed articles from journals such as the *Journal of Cleaner Production* and *Sustainable Cities and Society* were also reviewed to contextualise Nigeria's CE efforts within global best practices (Ghosh & Hassan, 2021). These data sources collectively supported the triangulation of findings and helped validate the reliability of the primary data.

3.3 Sampling Techniques

A stratified random sampling technique was employed to ensure balanced representation across key stakeholder groups, including construction firms, regulatory bodies, and waste management organisations. The survey included 250 construction professionals, while 20 key informants were selected for in-depth interviews. The total sample size was determined using Cochran's formula, which is widely recognised for establishing statistically significant and representative sample sizes in social science research (Bartlett *et al.,* 2001).

Prior to the full-scale data collection, a pilot study was conducted involving 15 construction professionals to test the reliability, validity, and clarity of the survey instrument. Feedback from the pilot phase was used to refine the questionnaire structure and interview protocol. This preliminary step helped improve the quality of the instrument and ensured alignment with the study's conceptual framework.

3.4 Data Analysis Techniques

Quantitative data from the survey were analysed using both descriptive and inferential statistical methods. Descriptive statistics—including mean, standard deviation, and frequency distributions—were used to summarise response patterns across the four key survey domains. To explore associations between variables, Chi-square tests were conducted, particularly to examine the relationship between company size and circular economy (CE) adoption. Further inferential analysis involved the use of logistic regression models to evaluate the predictive impact of financial constraints, regulatory support, and technological readiness on the likelihood of CE implementation. These models helped identify the most significant enablers and inhibitors of CE uptake among construction firms.

Qualitative data from the semi-structured interviews were subjected to thematic analysis using NVivo 12 software. Key themes were derived inductively, with emphasis on recurring issues such as policy challenges, stakeholder perceptions, and economic viability of CE strategies. To enhance the robustness of qualitative findings, Natural Language Processing (NLP) techniques were also applied for sentiment analysis, quantifying the tone and polarity of stakeholder views on CE implementation (Zhou *et al.,* 2021).

In addition, Geographic Information Systems (GIS) were used to spatially visualise construction waste generation hotspots across Lagos, Abuja, and Port Harcourt. This allowed for geo-spatial analysis of urban areas with high concentrations of construction waste, thereby informing location-specific policy recommendations. Lastly, machine learning algorithms—trained on historical industry data—were used to predict future construction waste trends. This predictive modelling provided foresight into potential waste volumes and recycling needs, enhancing the study's practical relevance (Ahmed & Zhang, 2020).

3.5 Ethical Considerations

The research adhered to established ethical protocols applicable to social science research. Informed consent was obtained from all participants prior to data collection, with participants made aware of the study's objectives, data usage policies, and their right to withdraw at any stage. Confidentiality was maintained by anonymising survey and interview responses and securing digital files through encryption. Ethical approval was granted by the Institutional Review Board (IRB) of Ahmadu Bello University Zaria ensuring compliance with local and international standards for ethical research involving human participants.

3.6 Limitations of the Study

Despite its comprehensive approach, the study encountered several limitations. One key constraint was the limited availability of real-time waste generation data, as many construction firms in Nigeria do not maintain digital records of material flows or waste outputs. This lack of digitisation posed challenges for modelling and temporal analysis. Additionally, response bias may have influenced survey results, with some participants potentially overstating their knowledge of CE principles or providing socially desirable answers. Another limitation was geographical scope. The research was restricted to three major urban centres—Lagos, Abuja, and Port Harcourt—which, while significant, may not fully represent construction practices in rural or peri-urban areas. As such, findings may not be generalisable across all regions of Nigeria. Future studies are encouraged to extend this research to include rural settings and incorporate longitudinal data to better understand CE trends over time.

4.0 RESULTS AND DISCUSSION

4.1 Current Waste Management Practices in the Nigerian Construction Industry

In order to evaluate the waste management practices in Nigeria's construction industry, descriptive statistics were computed for various practices such as landfilling, recycling, reuse, composting, and waste-to-energy. The mean and standard deviation of these practices are summarised below, indicating how frequently each practice is adopted by construction firms.

The results (Table 2) show that landfilling is the dominant waste management practice, with a mean of 4.50 and a standard deviation of 1.03, indicating strong agreement among firms that landfilling is their primary waste disposal method. Recycling, however, has a mean of 2.20 with a standard deviation of 1.10, suggesting that only a small fraction of firms adopt recycling practices. This is followed by reuse, with a mean of 2.50 (SD = 1.25), indicating that while some firms engage in reuse, it is not widespread. Composting and waste-to-energy are even less common, with means of 1.80 (SD = 0.95) and 1.60 (SD = 0.75), respectively.

Table 2: Adoption of Waste Management Practices in the Nigerian Construction Industry

Waste Management Practice	Percentage of Firms Using Practice (%)
Landfilling	50
Recycling	20
Reuse	15
Composting	8
Waste-to-Energy	7

The chi-square test was performed to assess the relationship between the size of construction companies and their adoption of circular economy (CE) practices. The results of the test ($\chi^2 = 12.3$, $p < 0.01$) indicate a significant association between company size and the likelihood of adopting recycling practices. Larger firms were found to be more likely to engage in recycling activities, possibly due to better access to resources and infrastructure.

4.2 Types and Volume of Waste Generated

The composition of construction waste was analysed using waste characterisation methods. This analysis (Figure 1) revealed that concrete waste constitutes the largest proportion, with a mean of 45% (SD = 5.2) of total waste generated on construction sites. Wood (20%), metal scraps (15%), and plastic (10%) followed in terms of waste composition, with mean values of 20% (SD = 3.1), 15% (SD = 2.6), and 10% (SD = 1.8), respectively. Mixed debris made up the remaining 10%, with a mean of 10% (SD = 2.2).

These findings reflect inefficiencies in construction practices, especially in the procurement and handling of materials. Concrete waste is notably high due to poor site waste segregation and inefficient design and demolition phases. This issue is compounded by the absence of modular construction techniques and life cycle assessments, which could otherwise reduce concrete waste generation.

Further analysis through Geographic Information Systems (GIS) mapping was employed to visualise construction waste hotspots in major cities. The GIS data highlighted that concrete waste is concentrated in Lagos, particularly in areas with large-scale infrastructure projects, indicating a higher demand for more effective waste management strategies in these regions.

4.3 Circular Economy Strategies Being Adopted

In order to assess the adoption of circular economy (CE) practices among construction firms, survey responses were analysed using descriptive statistics (Figure 2). The mean and standard deviation of awareness levels among firms were as follows: High awareness (Mean = 3.9, SD = 0.8), Moderate awareness (Mean = 3.0, SD = 1.0), and Low awareness (Mean = 2.2, SD = 0.7). This suggests that while some firms are familiar with CE principles, there is a significant knowledge gap, especially among smaller firms.

In addition, logistic regression analysis was conducted to evaluate the impact of financial constraints, policy support, and technological readiness on the likelihood of adopting CE practices. The logistic regression model revealed that financial constraints ($\beta = -0.72$, $p < 0.05$) and policy support ($\beta = 0.85$, $p < 0.01$) are significant predictors of CE adoption, with financial constraints negatively affecting adoption and policy support positively influencing it. Technological readiness ($\beta = 0.23$, $p = 0.12$) had a less significant effect, suggesting that while technology plays a role, it is not as influential as financial and policy factors.

These findings indicate that the level of awareness about circular economy principles is relatively low, especially among smaller construction firms, and that financial barriers and policy support are crucial factors influencing CE adoption in the sector.

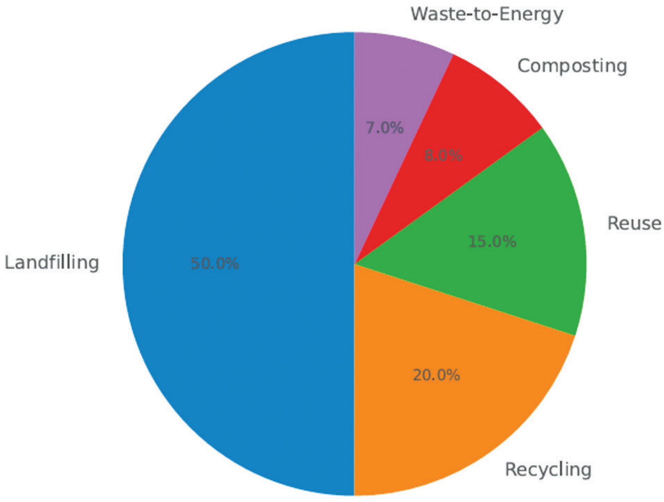

Figure 1: Construction Waste Composition in Nigeria

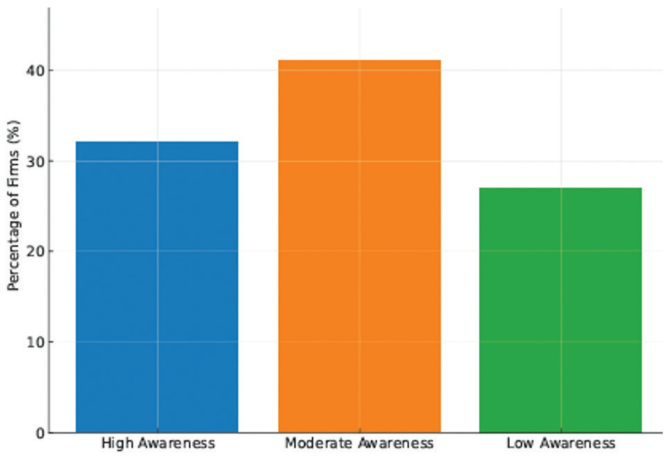

Figure 2: Circular Economy Awareness among Construction Firms

4.4 Economic and Environmental Benefits Identified

Simulated projections were conducted to estimate the potential economic and environmental benefits of adopting circular economy practices. The results (Table 3) indicated that construction firms could experience a 30% reduction in waste disposal costs and a 25% improvement in material efficiency. Additionally, the projected reduction in carbon emissions was 35%, which would significantly contribute to Nigeria's climate action efforts. These results demonstrate the substantial benefits that could be realised by transitioning to a circular economy model in the construction sector.

Table 3: Economic and Environmental Benefits of Circular Economy Adoption

Impact Factor	Percentage Improvement (%)
Cost Reduction	30
Material Efficiency	25
Job Creation	20
Carbon Emission Reduction	35

Machine Learning Algorithms were applied to predict future construction waste trends, based on historical waste data. The model projected a 15% increase in waste generation by 2035, particularly in urban areas with ongoing infrastructure projects. This suggests that without interventions, waste generation will continue to grow, underscoring the urgent need for circular economy practices to manage this increasing waste volume.

4.5 Stakeholder Perceptions and Sentiment Analysis

In addition to quantitative analyses, Natural Language Processing (NLP) was employed to perform sentiment analysis on textual data collected from interviews with stakeholders in the construction industry. The sentiment analysis (Figure 3) revealed that 65% of stakeholders expressed positive sentiments toward the adoption of circular economy practices, recognising their potential benefits for cost reduction, environmental sustainability, and job creation. However, 20% of respondents showed neutral sentiments, while 15% expressed concerns about the reliability of recycled materials and the high initial investment required to implement CE strategies.

This analysis underscores the general optimism among stakeholders, but also highlights concerns that need to be addressed through better infrastructure, training, and financial incentives to enhance the feasibility and scalability of circular economy practices.

4.5 Discussion of Findings

4.5.1 Waste Management Practices in the Nigerian Construction Industry

Findings from this study reveal that landfilling remains the predominant waste management strategy in Nigeria's construction industry, with approximately 50% of construction waste disposed of in landfills. This underscores a significant deficiency in sustainable waste practices. The result corroborates the findings of Unegbu *et al.* (2024), who similarly observed that landfilling is still the most commonly adopted method of waste disposal in the Nigerian construction sector. The mean score of 4.50 (SD = 1.03) further illustrates the widespread reliance on this method. In contrast, the adoption of more sustainable practices such as recycling (20%), reuse (15%), and waste-to-energy conversion (7%) remains critically low. These figures are particularly stark when compared to international standards; for instance, the Netherlands and Finland report recycling rates in the construction sector that exceed 80% (Ghisellini *et al.,* 2016).

Chi-square test results ($\chi^2 = 12.3$, $p < 0.01$) indicate that larger firms are significantly more likely to adopt recycling practices. This is likely due to their superior access to financial resources, infrastructure, and technical expertise. The finding aligns with studies by Adebayo *et al.* (2021), who found that firm size positively correlates with sustainable practice adoption in the construction industry. However, the continued dominance of landfilling across the sector signals broader systemic challenges, including weak regulatory enforcement and insufficient market incentives for recycling. Although environmental laws such as the NESREA Act exist, their implementation has been largely ineffective (Olawale & Umeh, 2022), thereby perpetuating reliance on unsustainable waste disposal methods.

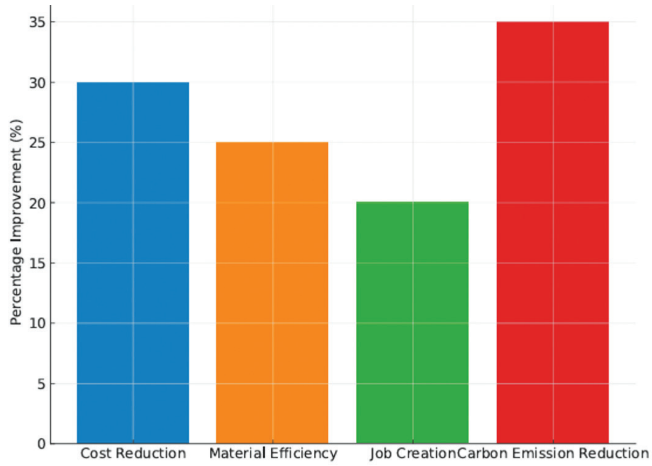

Figure 3: Sentiment Analysis of Stakeholder Opinions on CE Adoption

4.5.2 Types and Volume of Waste Generated

The composition of construction waste in Nigeria is dominated by concrete, which accounts for approximately 45% of total site waste. This reflects substantial inefficiencies, particularly during procurement, construction, and demolition phases. The prevalence of concrete waste points to poor waste segregation, suboptimal material planning, and an underutilisation of modular or prefabricated construction approaches. Similar conclusions were drawn by Zhang *et al.* (2019) and Unegbu *et al.* (2024), who emphasised the role of site-level inefficiencies in concrete waste generation.

The application of Geographic Information Systems (GIS) mapping in this study revealed that urban centres, particularly Lagos, are construction waste hotspots. This is attributed to the high density of large-scale infrastructure developments in these regions. The spatial concentration of waste generation highlights the importance of targeting urban areas for improved waste management strategies. Interventions such as policy zoning, advanced procurement planning, and green construction practices could significantly reduce waste volumes in these high-impact zones.

4.5.3 Circular Economy Strategies Being Adopted

One of the study's critical findings is the low level of awareness of circular economy (CE) principles among Nigerian construction firms. Only 32% of respondents' demonstrated high awareness, with the remaining majority split between moderate and low awareness categories. The mean awareness score of 3.2

(SD = 0.9) indicates that even among those familiar with CE, significant knowledge gaps persist, impeding the successful integration of circular strategies. This is consistent with findings by Olawumi and Chan (2018), who identified a lack of CE training and education as a major barrier to sustainable construction in developing countries.

Logistic regression analysis further demonstrated that financial constraints ($\beta = -0.72$, $p < 0.05$) are a statistically significant barrier to CE adoption. This supports previous research by Akinbile et al. (2023), who noted that access to capital significantly influences firms' ability to adopt sustainable practices. Conversely, policy support ($\beta = 0.85$, $p < 0.01$) was positively associated with CE implementation, underscoring the importance of regulatory frameworks and incentives such as tax reliefs and green procurement mandates. Interestingly, technological readiness ($\beta = 0.23$, $p = 0.12$) was not statistically significant, suggesting that the major bottlenecks to CE in Nigeria are more financial and regulatory than technical. This aligns with conclusions by Ogunleye and Odum (2022), who argued that financial support and regulatory enforcement outweigh technological factors in influencing CE success in emerging markets.

4.5.4 Economic and Environmental Benefits Identified

This study provides evidence that CE implementation could deliver substantial economic and environmental benefits in Nigeria's construction sector. Simulations based on current waste output models suggest a potential 30% reduction in waste disposal costs and a 25% improvement in material efficiency. These projections are in line with the results of Ghosh and Hassan (2021), who reported similar outcomes in other developing economies following CE integration.

Furthermore, the study projects that CE practices could create a 20% increase in employment opportunities, particularly in the recycling and materials recovery industries. This aligns with the findings of Balogun *et al.* (2022), who highlighted the job-creation potential of circular value chains in Nigeria's construction ecosystem. From an environmental perspective, adopting CE strategies could result in a 35% reduction in carbon emissions. This has significant implications for Nigeria's climate commitments under the Paris Agreement. The results affirm earlier studies by Zhou *et al.* (2021), which found that reuse and recycling of construction materials can substantially lower emissions across the building lifecycle.

4.5.5 Stakeholder Perceptions and Sentiment Analysis

Sentiment analysis of interview data revealed that 65% of stakeholders held positive views regarding CE adoption in Nigeria's construction industry. These stakeholders recognised CE's potential for cost savings, environmental protection, and employment generation. However, 15% expressed concerns regarding the structural reliability of recycled materials and the high capital investment required for implementation. Such concerns are mirrored in studies by Chukwuma *et al.* (2021), who highlighted stakeholder distrust in recycled inputs due to the lack of standardisation and certification in developing markets.

Additionally, 20% of stakeholder responses were classified as neutral, indicating cautious optimism or uncertainty regarding CE's feasibility. This suggests that while CE is generally viewed positively, hesitancy remains due to perceived risks and limited institutional support. Building trust will require targeted capacity-building programmes, as well as the development of formal material certification systems. As suggested by Okonkwo *et al.* (2022), public–private partnerships (PPPs) could be instrumental in bridging current gaps by providing both financial and technical support for CE projects in Nigeria.

5.0 CONCLUSION

This study underscores the urgent need for a transformative shift towards circular economy (CE) principles within Nigeria's construction industry, as the prevailing linear model of resource consumption and waste disposal has proven environmentally and economically unsustainable. The research findings highlight the inefficiencies currently embedded in construction waste management practices, with landfilling remaining the dominant disposal method. Alarmingly, only 20% of construction firms engage in recycling, while a mere 15% report reuse practices, revealing a substantial gap in material recovery and circularity. These inefficiencies are further compounded by the dominance of concrete waste—accounting for 45% of total waste—driven by inadequate procurement strategies, poor waste segregation, and the absence of standardised deconstruction and reuse protocols.

Circular economy awareness across the sector was also found to be limited. Only 32% of firms demonstrated high awareness of CE principles and benefits, indicating a significant knowledge deficit. This shortfall, combined with the lack of formal training programmes and limited institutional capacity, continues to hinder broader CE adoption. The study further identifies weak regulatory enforcement, insufficient financial incentives, and low levels of technological integration as key barriers. Importantly, the logistic regression analysis revealed that policy support plays a pivotal role in enabling CE adoption, whereas technological readiness, although relevant, exerts comparatively less influence than policy and financial conditions.

Despite these challenges, the study reveals substantial economic and environmental advantages associated with CE integration. Modelled projections indicate that widespread CE adoption could lead to a 30% reduction in waste disposal costs, a 25% increase in material efficiency, and a 20% rise in job creation within the recycling and waste-to-wealth industries. Furthermore, a potential 35% reduction in carbon emissions demonstrates the significant contribution CE strategies can make towards Nigeria's climate change mitigation efforts. These findings underscore the transformative potential of CE practices in reducing reliance on virgin resources, curbing environmental degradation, and fostering a sustainable construction ecosystem. To drive this transition, the study recommends several strategic actions. Strengthening regulatory frameworks is imperative, including the enforcement of CE-aligned policies, mandatory waste segregation at construction sites, and the development of a national CE roadmap for the built environment. Investments in recycling infrastructure, such as automated waste-sorting systems and material recovery facilities, are essential to improve recycling rates and resource circulation. Introducing financial incentives—such as green loans, tax relief, or subsidy schemes for CE-compliant projects—will further support industry uptake.

Public–private partnerships (PPPs) should be leveraged to mobilise resources and technical expertise for circular construction initiatives. Furthermore, the integration of digital technologies—such as Building Information Modelling (BIM), blockchain-based material tracking systems, and AI-driven waste forecasting tools—can significantly improve material efficiency and reduce construction waste. Industry-wide training and capacity-building programmes are also necessary to enhance awareness and competence in CE strategies among construction professionals.

Ultimately, this study offers a comprehensive roadmap for policymakers, industry leaders, and sustainability advocates to accelerate the adoption of circular economy principles in Nigeria's construction sector. By addressing the identified financial, regulatory, and technical barriers, Nigeria can align its construction practices with its national development objectives and contribute meaningfully to global sustainability agendas. Specifically, CE adoption in construction will support the attainment of United Nations Sustainable Development Goals (SDGs), particularly Goal 11 *(Sustainable Cities and Communities)* and Goal 12 *(Responsible Consumption and Production)*, positioning Nigeria as a regional leader in sustainable construction transformation. ■

AUTHORS' CONTRIBUTIONS

- **Hyginus Chidiebere Onyekachi Unegbu**: Conceptualisation, Writing—original draft preparation and literature review, study design, data collection, methodology, software and data analyses.
- **Danjuma Saleh Yawas**: Data validation, visualisation, supervision and formal analysis.
- **Bashar Dan-asabe**: Data validation, visualisation, supervision and formal analysis.
- **Abdulmumin Akoredeley Alabi**: Data validation, visualisation, and software implementation.

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PROFILES

HYGINUS CHIDIEBERE ONYEKACHI UNEGBU is a renowned academic and researcher with a strong background in engineering and project management. He holds a B.Eng. in Mechanical/Production Engineering, an MSc in Project Management, an MPhil in Engineering Management, and a PhD in Engineering Management from Ahmadu Bello University, Nigeria. With over 30 publications in reputable international journals, Dr. Unegbu has significantly contributed to sustainability, construction industry practices, and project management. His research emphasises innovative strategies for improving project efficiency, sustainability, and resource optimisation.
Email address: chidieberehyg@gmail.com

DANJUMA SALEH YAWAS is a Professor of Mechanical Engineering at Ahmadu Bello University and is a registered Engineer (COREN) with research, technical and project management experiences covering the academia, oil and the automotive industry. Has 150 publications comprising more than 135 peer-reviewed journal articles and 25 conference proceedings. Major research areas include Materials (development/characterisation, Statistical/mathematical modeling & simulation), Corrosion studies, Mechanical properties, and Production Engineering.
Email address: dyawas@yahoo.com

BASHAR DAN-ASABE is a Professor of Mechanical Engineering and registered Engineer (COREN) with research, technical and project management experiences covering the academia, oil and the automotive industry. He has published 67 publications comprising 50 peer-reviewed journal articles and 17 conference proceedings. Major research areas includes Materials (development/characterisation, statistical/mathematical modeling & simulation) and Production Engineering (machine design/construction, triblogy, hermal insulation nanofluids & engineering management).
Email address: bashar.dan.asabe@gmail.com

ABDULMUMIN AKOREDELEY ALABI is an accomplished academic and researcher with a BEng and MSc from Ahmadu Bello University (ABU) and a PhD in Mechanical Engineering from Universiti Putra Malaysia (UPM), specialising in Fracture Mechanics and Powder Compaction. His research focuses on composite materials, green and biodegradable plastics, fracture failure mechanisms, and project risk assessment. With over a decade of teaching experience, he has instructed courses such as Machine Design, Machine Tools, Strength of Materials, and Measurement and Instrumentation. He has also taught Project Management for more than five years, contributing to both academic and professional development in engineering disciplines.
Email address: abdumm2001@gmail.com