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UPCYCLING PLASTIC WASTE INTO BUILDING BLOCKS: A SUSTAINABLE STRATEGY FOR WASTE MANAGEMENT AND CONSTRUCTION IN KANO METROPOLIS, NIGERIA

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Abstract

Environmental degradation, driven by inadequate solid waste management, poses a significant barrier to achieving the Sustainable Development Goals (SDGs) in rapidly urbanizing cities like Kano Metropolis, Nigeria. This study assesses the potential of a circular economy approach, transforming plastic waste into durable building blocks, as a sustainable environmental and socio-economic strategy. Employing a mixed-methods design, the research established baseline data through waste composition analysis across low, medium, and high-density residential areas and major dumpsites, revealing a household waste generation rate of 0.56 kg/person/day and a substantial inorganic fraction (30-40%), dominated by plastics such as low density polyethylene (LDPE), polypropylene (PP), and polyethylene terephthalate (PET). The study evaluated low-cost, low-energy upcycling technologies involving shredding, low-temperature melting, and compression molding, deemed suitable for inclusive adoption by women and informal waste pickers. A stakeholder value chain analysis identified both opportunities (e.g., reduced material costs, new income streams) and barriers (e.g., standardization, regulatory approval) for integrating plastic bricks into Kano's construction industry. The findings demonstrate that plastic upcycling can simultaneously address environmental pollution, reduce construction material costs, and create inclusive livelihoods. The study concluded the needs for a framework for implementing this innovation, advocating for policies that support circular economy practices, inclusive technology adoption, and the development of performance standards for alternative building materials.

Keywords: *Plastic Waste, Circular Economy, Solid Waste Management, Informal Sector, Sustainable Construction.*

Introduction

Environmental degradation remains one of the most pressing global challenges, critically impeding progress towards the Sustainable Development Goals (SDGs), particularly in developing urban centers (United Nations, 2020). Kano Metropolis, a major Nigerian urban agglomeration, exemplifies this crisis, grappling with the compounded pressures of rapid population growth, inefficient waste management systems, and unsustainable environmental practices (Nabegu, 2010; Adamu & Nabegu, 2014, Ibrahim *et al*., 2025). Municipal solid waste (MSW) in Kano is heterogeneous, with inorganic components, especially persistent plastic waste, constituting a significant portion (30-40%) and contributing to severe land, water, and drainage pollution (Akinbile *et al*., 2021; Okeniyi & Anwan, 2012).

The challenge of sustainable urban development is acute in Sub-Saharan Africa, where an estimated 56.2% of the urban population lives in informal settlements, highlighting a profound deficit in affordable housing (United Nations, 2020; UN-Habitat, 2016). Nigeria mirrors this crisis, with a national housing deficit exceeding 17 million units. Concurrently, unsustainable consumption patterns have led to a global material footprint of approximately 92 billion tonnes, with plastic waste representing a critical component of mismanaged materials (United Nations SDG Report, 2020; Plastic Atlas, 2020). Nigeria generates vast quantities of plastic waste, which, due to inefficient management, clogs drainage systems and pollutes ecosystems in cities like Kano (Akinbile *et al*., 2021).

The construction industry, a key sector for development, is itself a major polluter. Cement production, for instance, contributes about 7% of global CO_2 emissions (Baran, 2025). This creates a development conundrum: meeting housing and infrastructure needs often exacerbates environmental degradation. Technology and innovation are thus crucial for decoupling development from resource depletion and pollution (European Commission, 2004).

Research on converting plastic waste into construction materials such as paving stones, tiles, and building blocks has demonstrated technical feasibility (Alabi & Ologbonjaye, 2017; Baran, 2025). Plastic-sand composite blocks can meet minimum strength requirements for non-load-bearing applications, offering benefits like lightweight properties, water resistance, and potentially lower production costs (Baran, 2025; Awoyera & Adesina, 2020). However, challenges related to long-term durability, fire resistance, and the lack of standardized testing protocols remain significant barriers to widespread adoption (Awoyera & Adesina, 2020).

In Kano, the waste management landscape is fragmented. While private sector participation exists in low and medium-density areas, high-density areas home to about 80% of the population rely on inadequate communal collection systems managed by the state, revealing governance weaknesses (Adamu & Nabegu, 2014; Da'u, 2023). This gap underscores the need for community-participatory and technologically appropriate solutions (Da'u, 2023). Furthermore, the informal sector, including waste pickers, plays a vital but often undervalued role in resource recovery (Gutberlet, 2013). Inclusive approaches that empower these actors are essential for sustainable waste management (Gutberlet, 2014).

Despite the promising technical evidence, there is limited research on the socio-economic contextualization, large-scale implementation feasibility, and value-chain implications of plastic waste upcycling specifically within the unique urban context of Kano Metropolis. This study seeks to address these gaps.

The traditional waste management system, characterized by limited collection, open dumping, burning, and partial recycling, has proven inadequate (Malumfashi *et al*., 2011). Consequently, innovative and sustainable approaches are urgently needed to divert plastics from the environment and the linear economy. Upcycling converting waste materials into new products of higher value offers a promising pathway (Alabi & Ologbonjaye, 2017). This research explores the upcycling of plastic waste into building blocks, a strategy that addresses a triad of interconnected issues: environmental pollution from plastic waste, the high cost and carbon footprint of conventional construction materials like sandcrete blocks, and the socio-economic marginalization of key actors like women and informal waste pickers (Gutberlet, 2013; Wilson *et al*., 2006). The goal is to establish critical baseline waste data, identifies appropriate and inclusive technologies, and analyzes the potential integration of plastic-based blocks into the local construction value chain. By doing so, it provides a framework for a circular economy model that promotes waste diversion, low-carbon construction, and inclusive livelihood opportunities.

Materials and Method

Study Area

Kano Metropolis, the capital of Kano State, is situated in Nigeria's Sudan Savanna region, between latitudes 12°25'N and 12°40'N, and longitudes 8°35'E and 8°45'E (Figure 1). Historically, it has served as the primary commercial and industrial hub of northern Nigeria, attracting diverse populations both nationally and internationally. The metropolis encompasses eight local government areas (LGAs), with Dala, Fagge, Gwale, and Kano Municipal forming the historic core within the ancient city walls. Nassarawa and Tarauni LGAs constitute the metropolitan nucleus, bordered by Kumbotso and Ungogo. As Nigeria's second-most populous state capital, Kano spans approximately 683 km² at an elevation of 472 meters above sea level. The terrain is predominantly flat, with localized outcrops such as Dala and Goron Dutse hills (Falola, 2002; Madugu, 2016; Mohammed *et al.,* 2019). A recent projection put the population to almost 5 million inhabitants (Sawyerr, Opasola and Otto, 2025).

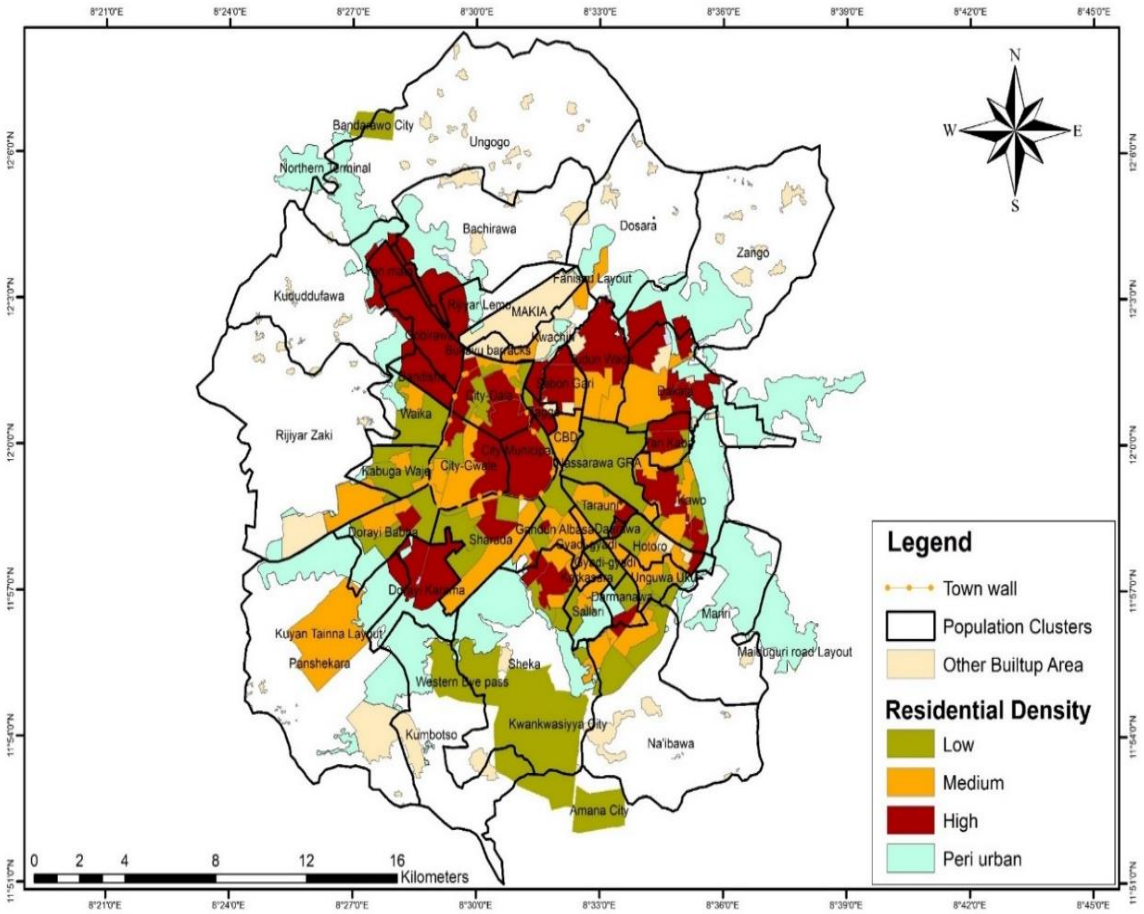

Figure 1: Kano Metropolis Showing Residential Density Classification
Source: Adapted from NIAF/KNUPDA (2014), Hassan (2016), Mohammed (2018) and Da'u (2023)

Data Collection and Sampling Method

A mixed-methods approach was employed, combining quantitative waste analysis with qualitative socio-economic assessment to provide a comprehensive evaluation. Generally, waste analysis stratification according to different residential structures and their locations are highly suitable (EC, 2004). So, a stratified sampling procedure was used to select 210 households (70 household from each stratum of low, medium, and high residential density areas). Two major dumpsites (Maimalari and Court Road) were purposively sampled based on the fact that these dumpsites forms the largest dumpsites among the four recognised formal dumpsite of the state, other two dumpsites were Bulukiya and Ladanai, when it comes to the ownership of the dumpsites only Court road dumpsite owned by Kano State Government through Kano State Ministry of Environment and Climate Change while Maimalari dumpsites owned by private individual, so these criteria encourage the selection of these dumpsites purposively.

Daily waste generated from sampled households were collected for seven days uninterrupted (EC, 2004), sorted, and categorized into fractions (plastics, paper, organic, etc.) and sub-fractions (e.g., Polyethylene terephthalate (PET), Low-density polyethylene (LDPE), High-density polyethylene (HDPE). Waste was weighed, and household demographic data was recorded.

Semi-structured interviews were conducted with key stakeholders: traditional block makers and builders were drawn from the low, medium and high density areas of Batawa, Kundila and Jaen respectively, architects from Kano State Urban Planning Development Authority (KNUPDA) and Ministry of Housing Cooperation, waste pickers from the Maimalari and Court Road dumpsites, and representatives from recycling firms from Dakata and Sharada recycling hubs Table 1. Interviews aimed to map the existing sandcrete block value chain, understand perceptions of alternative materials, and identify opportunities and barriers for plastic-based blocks.

Table 1: Sampling for Interview

Stakeholders Category	Number Interview	Location/Ministry/Department/Agency
Traditional block makers	6	Batawa, Kundila, Jaen
Builders	6	Batawa, Kundila, Jaen
Architechs	4	Kano State Urban Planning Development Authority (KNUPDA), Ministry of Housing
Waste Pickers	10	Maimalari dumpsite, Court Road dumpsite, Dorayi Gidan Sarki Collection Center, abd Refuse Management and Sanition Board (REMASAB)
Recycling firms	4	Dakata and Sharada
Total	**30**	

Analysis

Composition was calculated by weight percentage. Granulometric analysis separated waste into fine (<20 mm), medium (20-80 mm), and gross (>80 mm) fractions to identify suitable streams for composting and recycling.

Value Chain and Stakeholder Analysis

Technologies were evaluated based on criteria of simplicity, safety, affordability, low energy demand, capacity for small-scale production, and suitability for involvement by women and informal waste pickers. The assessment focused on identifying processes compatible with the dominant plastic types found in the waste audit.

Results and Discussion

Municipal Solid Waste (MSW) Characterization

The analysis of waste generation and composition across residential densities provides the foundational data necessary for planning targeted resource recovery interventions. The key metrics are summarized in Table 2.

Table 2: Key Waste Generation and Composition Metrics by Residential Density in Kano Metropolis

Metric	High Density	Medium Density	Low Density	Composite Average
Avg. Generation (kg/capita/day)	0.57	0.46	0.65	0.56
Compostable Fraction (%)	22.43	42.47	80.57	45.16
Total Recyclable Fraction (%)	12.34	10.92	9.07	11.12
Fine Fraction (<20 mm) (%)	46.56	30.79	38.54	38.63

The average per capita waste generation rate of 0.56 kg/day is consistent with figures reported for other Nigerian cities such as Lagos and Abuja, reflecting similar consumption patterns and living standards (Ogwueleka, 2009; Nabegu, 2010). However, a pronounced spatial disparity is evident in the composition. The compostable (organic) fraction exhibits an inverse relationship with population density, ranging from a low of 22.43% in high-density zones to a striking 80.57% in low-density areas. This gradient likely stems from socio-economic and lifestyle differences: low-density areas often correlate with higher-income households possessing greater space for yard waste and potentially engaging in more fresh food consumption, generating higher organic waste. Conversely, high-density, lower-income areas may rely more on processed foods and have less organic waste to discard (Nabegu & Mustapha, 2015). This has direct implications for waste management planning, suggesting that composting initiatives would yield the highest mass diversion in low and medium-density zones.

The recyclable fraction, while relatively low and stable (9-12%), represents a critical stream for resource recovery and circular economy initiatives (EC, 2004). Its consistent presence across all zones indicates a reliable, city-wide availability of recyclables, primarily plastics and metals. The granulometric analysis further reveals that the fine fraction (<20 mm) largely soil, dust, and degraded organic matter is the largest single category (38.63% average). This material is unsuitable for mechanical recycling but underscores the significant potential for composting or soil amendment projects to manage a major portion of the waste stream.

Plastic Waste Composition: Analysis of the Target Feedstock

Plastic waste was identified as the most promising inorganic feedstock for valorisation due to its volume, persistence, and material properties. Figure 2 & 3 summarize the composition of the key plastic polymers found in the gross fraction (>80 mm), which is the most suitable for mechanical recycling and upcycling processes and others in figure 2 stands fines fractions across other plastics or inorganic categories.

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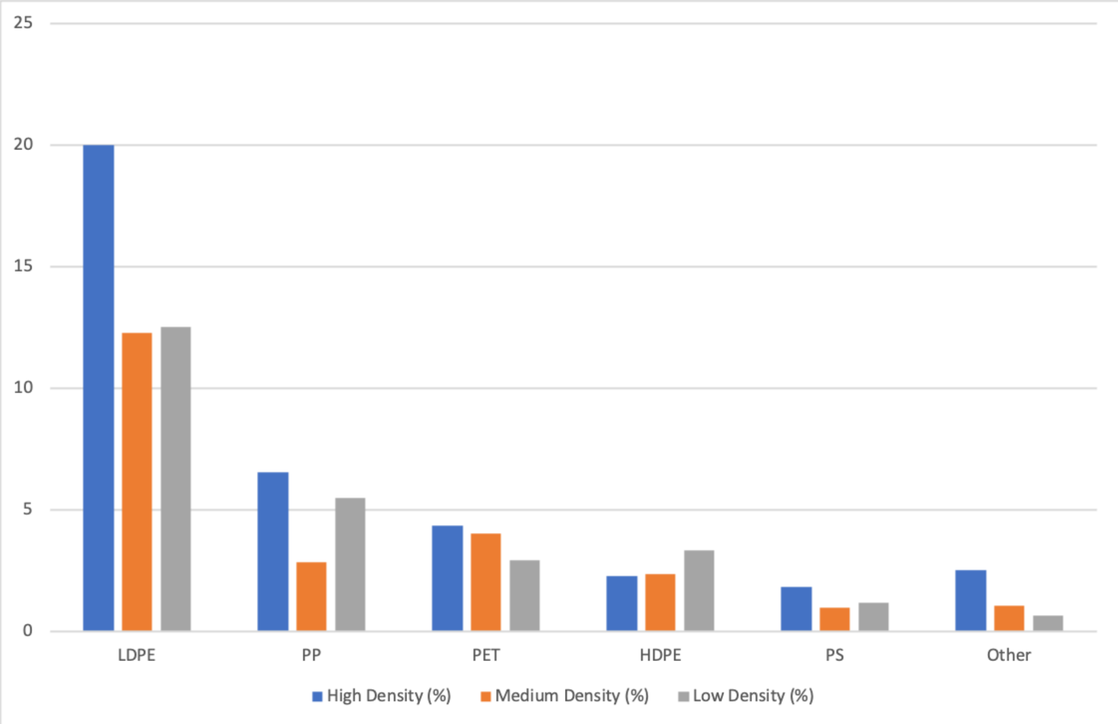

Figure 2: **Plastic Polymer Composition in Gross Waste Fraction (>80 mm)**

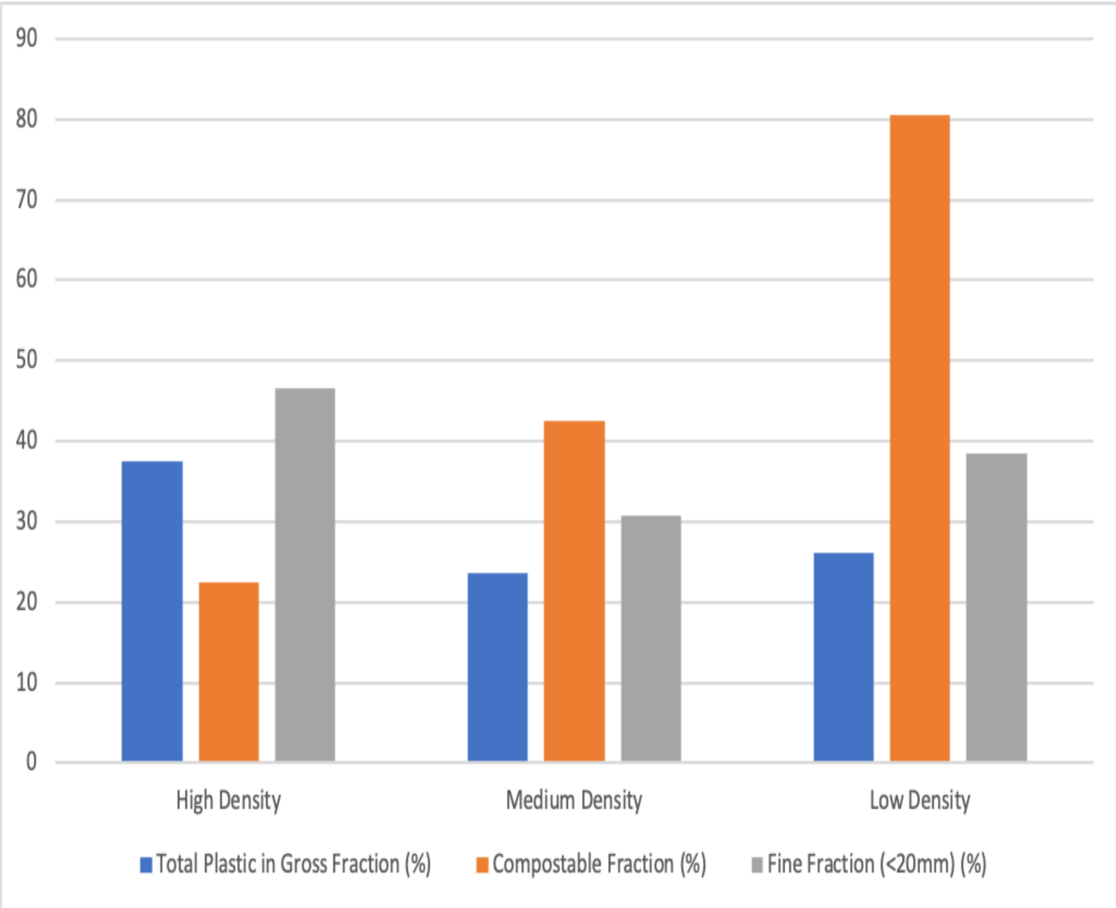

Figure 3: Overall Waste Stream Analysis by Residential Density

Table 3: Detailed **Polymer Analysis in the Gross Waste Fraction (>80 mm)**

Polymer Type	High Density (%)	Medium Density (%)	Low Density (%)	Mean ± SD (%)	Relevance for Upcycling
LDPE (Total)	19.97	12.29	12.53	15.26 ± 3.49	Primary feedstock. Low melting point (~120°C), excellent thermal binding properties.
Polypropylene (PP)	6.56	2.84	5.48	4.96 ± 1.60	Key secondary feedstock. Adds rigidity; compatible melting range with LDPE.
Polyethylene Terephthalate (PET)	4.33	4.01	2.91	3.75 ± 0.62	Requires higher processing heat; may be separated for dedicated recycling.
High-Density Polyethylene (HDPE)	2.26	2.38	3.33	2.66 ± 0.48	Good strength; can be incorporated but has a higher melting point.
Polystyrene (PS)	1.83	0.97	1.17	1.32 ± 0.37	Brittle; useful in low proportions for filler.
Total Plastic	37.48	23.55	26.06	29.36 ± 6.17	

The data in Table 3 confirms that plastic is a substantial and recoverable component of Kano's Municipal Solid Waste (MSW), constituting an average of 29.36% of the gross, recoverable fraction. This aligns with national concerns over rising plastic pollution (Akinbile *et al.*, 2021) and presents a tangible opportunity for diversion.

The clear dominance of Low-Density Polyethylene (LDPE), representing over half of the plastic mix (15.26% out of 29.36%), is the single most significant finding for technology design. LDPE's low melting point and ability to act as a binder when melted make it an ideal matrix material for composite blocks (Baran, 2025). The prevalence of black LDPE (recycled film) indicates a pre-existing, informal recovery loop, highlighting the potential to formalize and add value to the work of waste pickers who already collect this material (Wilson *et al.*, 2006).

Polypropylene (PP) serves as a complementary feedstock. While less abundant, its inclusion enhances the composite's structural rigidity. Critically, both LDPE and PP are polyolefins with compatible thermal processing windows, allowing them to be melted together without sophisticated segregation, a vital advantage for a low-tech, informal-sector-friendly model.

The relative uniformity of plastic types across the city evidenced by the standard deviations is advantageous. It suggests that a single, standardized upcycling process can be effectively deployed city-wide, simplifying training, scaling, and quality control.

However, challenges are noted. The presence of PVC (polyvinyl chloride), albeit in trace amounts in the overall sample (Table 3), necessitates caution due to the risk of chlorine gas emissions during uncontrolled heating. Furthermore, multi-layer composites (e.g., snack wrappers) present a recycling challenge. This underscores the need for a simple, visual sorting guide as part of the technology package to exclude non-compatible plastics, transforming a technical hurdle into a skill-development opportunity for workers.

From Waste Data to Technology Design

The waste characterization results directly and decisively inform the proposed upcycling system's design principles:

Feedstock-Centric Technology Choice: The abundance of low-melting-point polyolefins (LDPE/PP) validates the selection of low-temperature thermal processing (e.g., using locally fabricated ovens or heated molds) over more energy-intensive or complex methods. This approach minimizes energy costs, reduces the technological barrier, and enhances safety (Anthonio *et al*., 2024).

Pre-Processing Requirements: The fact that target plastics are concentrated in the gross (>80 mm) fraction justifies the essential step of shredding. A manually operated or low-power mechanical shredder would be sufficient to create uniform flakes, ensuring consistent melting and brick density a key factor for structural performance (Alabi & Ologbonjaye, 2017).

Product Formulation Strategy: The consistent polymer mix allows for a relatively standard "recipe." The LDPE acts as the melt-binding agent, while PP, HDPE, and PET fragments act as aggregate, reducing the need for large proportions of external sand. This directly addresses the study's aim of reducing dependence on natural sand resources (Yousif *et al*., 2025).

Model for Inclusive Implementation: The entire process chain (collection, manual sorting, shredding, melting, and molding) can be segmented into simple, trainable tasks. This modularity is crucial for integrating diverse participants, particularly women and informal waste pickers, by allowing them to engage at various levels based on their capacity and interest, fostering economic empowerment and inclusive governance in waste management (Gutberlet, 2014; Da'u, 2023).

Stakeholder Perspectives and Value Chain Analysis

The qualitative insights from stakeholder interviews (Table 4) reveal critical socio-economic and institutional dimensions that complement the technical waste data, offering a holistic view of the upcycling initiative's potential integration into Kano's local economy.

Table 4: Synthesis of Key Stakeholder Perspectives on Plastic-Based Building Blocks

Stakeholder Group	Key Concerns & Current Challenges	Perceived Opportunities	Major Barriers to Adoption
Builders & Contractors	Rising cost and inconsistent quality of conventional sandcrete blocks; uncertainty about new materials.	Potential for lower-cost, durable alternative building material; reduced dependence on scarce sand.	Lack of proven long-term durability and load-bearing capacity; absence of regulatory approval or official standards.
Block Makers (Informal/Small -scale)	Familiar with labor-intensive, low-margin sandcrete production; vulnerable to cement price volatility.	New product line compatible with simple molding techniques; potential for localized, low-energy production.	Initial cost of new molds/equipment; uncertainty of market acceptance and stable demand.
Architects & Engineers	Emphasis on material performance, safety standards, and reliability for design integrity.	Application in non-load-bearing partitions, landscaping, and innovative designs; interest in moisture-resistant properties.	No existing building codes or certification for plastic bricks; requires rigorous standardized testing data.
Waste Pickers & Informal Collectors	Reliance on volatile markets for low-value plastics (esp. LDPE); precarious and often hazardous working conditions.	New, stable income stream from supplying sorted plastic feedstock; potential for role in pre-processing (shredding).	Need for training on safe handling and sorting; requires guarantee of consistent offtake/purchase agreements.
Recycling Firms	Focused on high-value plastics (PET, HDPE); mixed/low-value plastics often treated as residue.	Provides a commercial outlet for non-recyclable or low-market-value plastic fractions, improving overall recycling economics.	Integration challenges with existing business models; perceived as a different operational sector.
Regulatory/Government (Implied)	Concern with public safety, environmental compliance, and urban planning.	Aligns with circular economy goals, SDGs, and sustainable urban waste management mandates.	Absence of formal policy frameworks, guidelines, or performance benchmarks for such alternative materials.

It is clear that Kano Metropolis has well-established traditional value chain for construction materials, centered on sandcrete blocks. The identified pain points are cost, quality, and resource scarcity which create a tangible market entry point for an alternative material. Builders' and block makers' openness to alternatives, provided they are cost-effective and reliable, indicates a readiness to adopt innovations that address their immediate economic pressures (Adamu & Nabegu, 2014).

The enthusiasm from waste pickers and informal collectors is a significant finding. They recognize upcycling as an opportunity to formalize and enhance their livelihoods by creating demand for currently low-value plastics. This aligns with principles of inclusive waste management, which advocate for integrating the informal sector into formal recycling chains to improve efficiency and equity (Gutberlet, 2013; Wilson *et al*., 2006). Their potential involvement in collection and pre-processing stages is crucial for ensuring a steady feedstock supply while providing socio-economic upliftment.

However, the convergent concern across builders, architects, and regulators regarding standards and certification represents the most substantial systemic barrier. This "institutional gap" outweighs mere technical feasibility. The success of plastic bricks hinges not just on their material properties but on their legitimization within the construction industry's regulatory and normative framework (Ibrahim *et al*., 2025). This underscores the necessity of parallel action: technical performance testing must be coupled with advocacy for policy innovation. Developing locally relevant product standards and working with agencies like the Kano State Ministry of Environment and Climate Change (MoECC) and Standards Organization of Nigeria (SON) is imperative for scaling beyond pilot projects (Da'u, 2023).

Furthermore, the perspective of formal recyclers highlights a potential synergistic relationship. An upcycling plant could act as a downstream sink for mixed plastic "waste" from sorting facilities, improving their overall recovery rates and economics. This suggests the model should be positioned as complementary, not competitive, to existing recycling efforts.

In synthesis, the stakeholder analysis reveals that while the technical and economic logic for upcycling is strong (supported by waste data and cost concerns), its socio-institutional acceptance is conditional. The path forward requires a tripartite strategy: 1) Technical Proof through rigorous production of test blocks and independent strength/durability analyses; 2) Market Creation via pilot projects with engaged builders and demonstration buildings; and 3) Policy Engagement to develop provisional standards and gain official endorsements. This integrated approach is essential for transitioning the upcycling model from a promising concept to a viable element of Kano's circular economy and sustainable construction landscape.

Conclusion and Recommendations

This paper validates the feasibility of upcycling of plastic waste into building blocks, multi-benefit strategy for Kano Metropolis. The analysis confirmed a substantial and suitable plastic feedstock, primarily LDPE and PP, enabling a simple, low-cost processing technology accessible to women and informal waste pickers. Stakeholder engagement revealed clear market interest but identified the lack of product standards and regulatory frameworks as the primary barrier to adoption.

Therefore, while the technical and economic rationale is strong, transitioning this model from concept to practice requires concurrent action: pilot-scale demonstrations to prove durability, and policy advocacy to develop supportive standards and incentives. Implementing this circular economy approach can simultaneously address waste pollution, reduce construction costs, and create inclusive livelihoods, contributing directly to Kano's sustainable urban development.

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