

Collaborative Valorisation of Agricultural Residues: A Framework for Sustainable Construction in Nigeria

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ABSTRACT

Nigeria generates significant amounts of Farm waste, which can be repurposed into sustainable building materials. However, the lack of a structured approach to innovation management hinders the effective utilization of these waste materials. The high Expenses associated with procuring construction inputs in Nigeria are creating a shortfall of conventional building materials, which in turn exacerbates the housing crisis in Nigerian urban areas. Given the above, there is an urgent need to produce low-cost, sustainable building materials that are affordable to the construction industry in Nigeria, thereby reducing the construction costs associated with the housing shortage in Nigeria. Despite growing interest in transforming waste materials into raw materials for building material production, the focus has predominantly centred on general household waste, with scant attention directed towards Farm waste materials. Indeed, Farm waste has been overlooked, and opportunities inherent in harnessing the burgeoning volumes of Farm waste remain largely untapped. Addressing this gap, this research integrates and analyses the organisational structures of the construction, manufacturing, and agricultural sectors to devise a framework facilitating enhanced utilisation of Farm waste residues in building material production. Adopting a mixed-methods approach grounded in a pragmatic philosophical stance, the study employs a case study strategy pursuing an abductive approach—synthesising elements of inductive and deductive methodologies. Data derivation encompasses the synthesis of extant literature reviews complemented by insights garnered through semi-structured interviews. Data was obtained through the synthesis of literature reviews, semi-structured interviews, and questionnaires from multiple cases from stakeholders' organisations in Nigeria. The research findings revealed that there is no existence of institutional actors that can assist in the utilisation of Farm waste for building construction purposes. The development of such a framework aims to facilitate the effective integration of stakeholders critical to implementing strategies for converting Farm waste into viable building materials. The developed framework shows an innovative organisational hierarchical process of how Farm waste residues can be used or converted into building materials that involves the government as well as other stakeholders. The framework underwent validation via a focus group comprising construction professionals, aimed at assessing its practical viability. Consequently, this study underscores an extant gap in the organisational infrastructure requisite for channelling Farm waste towards building construction applications. Furthermore, this research holds potential to inform policy discourse about the utilisation of Farm waste as construction materials, thereby addressing shortages of traditional building resources. This article proposes a collaborative innovation management framework to facilitate the development and implementation of Farm waste-based building materials in Nigeria. The framework emphasizes stakeholder engagement, knowledge sharing, and collaborative problem-solving to drive innovation and sustainability in the construction industry.

KEYWORDS

Agricultural, Resource Innovation, Business Management

I. INTRODUCTION

Agricultural residue production poses a considerable environmental challenge in Nigeria, with millions of tonnes generated yearly (Adebayo et al., 2020). Conversely, these by-products harbour transformative potential, serving as precursors for construction inputs (Oyenuga et al., 2019).

Leveraging agro-industrial leftovers for building components yields multifaceted advantages: mitigating disposal dilemmas, curbing construction expenditures, and bolstering ecological balance (Kolawole et al., 2020). Notwithstanding these merits, Nigeria's adoption of agri-waste-derived building elements encounters substantial barriers, chiefly stemming from awareness deficits, constrained R&D, and infrastructural inadequacies (Adebayo et al., 2020). Nigeria, home to over 177.2 million inhabitants as of July 2014, ranked seventh globally and topped Africa's demographic ladder. Projections indicated a 2.47% growth in 2014, forecasting an additional 50 million residents by 2020 (World Bank, 2013).

The nation exhibits extraordinary linguistic heterogeneity, harbouring over 500 languages; prominent tongues include Hausa, Yoruba, and Igbo, alongside English (the official language). English serves as a lingua franca in commerce, academia, and governance. Estimates posit Nigeria's 2030 population between 250 and 295 million. Critically, a staggering housing shortfall of circa 28 million units – predominantly urban – impacts over 180 million Nigerians (Yakub, Salawu, & Gimba, 2022). With 60-70% urban residency, this deficit's repercussions are severe; absent affordable housing and amenities, Nigeria faces heightened vulnerability (Yakub et al., 2012). Former President Obasanjo described Lagos (2001) as an "urban jungle" unsuitable for habitation. UN surveys quantify Nigeria's housing gap at roughly 28 million units. Government targets include delivering 300,000 units via the Renew Hope Housing Scheme (2025). Cost-effective, sustainable building materials are imperative to alleviate urban-rural housing pressures (Taiwo & Adeboye, 2013). Lately, interest has surged in repurposing waste for construction material production, offering alternatives to pricey conventional inputs (Oladipo & Oni, 2012). Focus, however, leans towards municipal waste; agro-residues remain relatively overlooked. Farm waste utilisation opportunities – transforming abundant residues into affordable building material feedstock – appear underleveraged (Oladipo & Oni, 2012).

II. CO-CREATIVE INNOVATION GOVERNANCE MODEL

There is no doubt that comfort, convenience, and efficiency in everyday life are positively aided by innovation (Reddy and Reddy, 2014). The subject of innovation is important to other disciplines, including pure science, engineering, and the social sciences. Banerjee (2011, p.11) highlights this point by noting that "due to its widespread effect, innovation is an important topic in the study of economics, business, entrepreneurship, design, technology, sociology, and engineering in everyday life". Since innovation has been studied in various disciplines and under different environmental influences, the term continues to be confusing. It has sometimes been related to organizational change, design, invention, and creativity. Similarly, there is also a lack of agreement amongst researchers regarding the core meaning or definition of the term 'innovation'. Nevertheless, there are

several convergences in most definitions of innovation as noted by successive researchers.

Dodgson and Bessant (1996, p. 31) define "Innovation as the process through which an organization structure seeks to acquire and build upon its distinctive technological competence, understood as the set of resources an organization possesses and how these are transformed by innovative capabilities and collaborations". Their definition does not indicate that innovation could also be 'destructive' in nature. There is also a hint that their definition is restricted to organizational processes, thus omitting other innovative areas, like new product development. A relatively recent addition to the innovation sub-theme is the market exploitation of qualifications for innovation. "Innovation means the application of new knowledge to industries, and includes new products, new processes, social and organizational change" (Firth & Mellor, 1999, p.199). Critically, Firth and Mellor's (1999) definition does not highlight the impact of innovation on the environment, as proposed by Atkin et al. (2009, p.196), who assert that "innovation achieved is when an invention or an idea begins to impact the environment". There is also an underlying requirement that, for the outcome of an innovation effort to achieve successful market exploitation, it must meet specific customer/market needs and requirements. Thus, Clark and Fujimoto (1991, 132) argue that innovation is "the development of new values through solutions that meet new requirements, unarticulated needs, or old customer and market needs in a value-adding new way". The basis of Clark's definition lies in the logic that it is only when the innovation adds value to the customer that the innovating organization can retrieve the value by way of added revenue or profit.

Nevertheless, there is also the question as to the degree of newness required of a creative idea for it to be considered 'innovative'. Egbu et al. (2001) attempt to resolve this question; they note that innovation is the exploitation of the new. Emphasis has been placed on the phrase "new to the unit of adoption" or "where the idea is new to a particular context" (Egbu et al. 2001, p. 186). This indicates that, for a creative idea to be categorised as an "innovation", it must be "new to the unit of adoption". The unit of adoption could be a country, city, industry, organisation, or department of an organisation. Whilst the above definitions are important, the present study adopts the definition offered by Dodgson & Bessant (1996, p127) who argue that innovation "is the process through which organisation structure seeks to acquire and build upon their distinctive technological competence, understood as the set of resources an organisation possesses and how these are transformed and managed by innovative capabilities and collaboration" (Dodgson and Bessant, 1996; Lawson and Samson, 2001). The framework for adoption is in line with the organisational innovation management structure framework that will help in the utilisation of Farm waste for building material production. In reviewing the definitions of innovation discussed in the previous section, a few common sub-themes can be extracted. These commonalities include the newness of the conceived idea; the deliberate application of information by the organisation, how the innovative ideas have been managed by organisations; the collaboration of industries and stakeholders to create new ideas and products; the perceived value by the end-user; and the successful exploitation of the new idea. This will help in the production of building construction material from waste products. Thus, having reviewed relevant literature about the definition of innovation, to understand the importance of this definition, it is important to understand the theories that guide innovation. The next section will discuss relevant literature about innovation theories.

III. THEORY OF INNOVATION

Innovation undeniably enhances comfort, convenience, and efficiency in daily life (Reddy & Reddy, 2014). Its significance spans disciplines like pure science, engineering, and social sciences. Banerjee (2011) underscores innovation's pervasive impact, noting its relevance in economics, business, entrepreneurship, design, technology, sociology, and engineering.

Despite interdisciplinary study, innovation remains a concept with varying interpretations, often intertwined with organisational change, design, invention, and creativity. Definitions lack a universal consensus among researchers. Dodgson and Bessant (1996) describe innovation as an organisational process leveraging distinctive technological competence through resources, capabilities, and collaborations. This view focuses on organisational aspects, omitting potential 'destructive' innovation facets and areas like new product development. Firth and Mellor (1999) broaden the scope, linking innovation to applying new knowledge for new products, processes, and socio-organisational changes. Atkin et al. (2009) stress innovation's environmental impact, defining it via invention or ideas affecting the surroundings. Clark and Fujimoto (1991) tie innovation to creating new value, meeting articulated/unarticulated needs innovatively.

Egbu et al. (2001) highlight innovation as exploiting 'newness' relative to adoption contexts – new to a country, industry, organisation, etc. This study aligns with Dodgson and Bessant's (1996) definition, focusing on organisations acquiring/building technological competence via resources, capabilities, and collaboration (also Lawson & Samson, 2001). Key recurring themes in innovation definitions include: newness of ideas; organisational application of knowledge; management of innovative concepts; stakeholder collaboration; perceived end-user value; and successful exploitation of novelty. These aspects bear relevance for utilising agricultural waste in building material production. Understanding innovation's theoretical underpinnings is crucial; subsequent sections explore pertinent innovation theories.

IV. FACTORS AFFECTING INNOVATION IN CONSTRUCTION

According to Egan (2002), existing literature tends to agree that productivity, value for money, and overall client satisfaction in the construction industry are fairly low compared with other industrial sectors and that the reasons for low client satisfaction are due to several factors. These factors are mutually dependent, as they support each other (Cox and Townsend, 1998; Hardie and Newell, 2011). A substantial body of work across the construction sector and related disciplines converges on the notion that transformation is imperative, necessitating a unified endeavor among industry players to address burgeoning requirements. However, to achieve the desired demand for innovation, the characteristics of a successful innovation process must be achieved, and this is essential in a construction process that is already noted as sub-standard (Cox and Townsend, 1998). Some general factors, which contribute to the problems of the construction industry, can be found in a range of literature (Cox and Townsend, 1998; Hardie and Newell, 2011); these factors are summarized as:

An adversarial culture, Changes in specifications, Cyclic demands, Fragmented industrial structure, Inappropriate procurement forms, Inappropriate allocation of risk, Inefficient

methods of construction, Management problems, Poor quality.

Also, Manley (2008) argued further that, through competence and knowledge, communication, learning, relationships, and co-operation with other parties (professionals), an organization designs details to the simplest level to enable easy interpretation, and this forms part of the factors that affect construction innovation. Manley's perspective overlooks the determinants shaping these factors. Conversely, Gordon (1994) elucidates these influences, framing them as partnership dynamics integral to construction processes.

He posits that diverse procurement/contract modalities and collaborative arrangements significantly modulate innovation trajectories in construction. Cumulatively, these elements – intertwined with partnership configurations – profoundly impact construction industry innovation, partly due to the complexities inherent in Complex Products and Systems (CoPS) that impede innovative endeavors. Consequently, mitigating obstacles to construction innovation necessitates adopting tailored frameworks and structures conducive to fostering an efficacious innovation ecosystem, particularly pertinent in Nigeria's construction context.

V. INNOVATION TRAJECTORIES IN THE NIGERIAN CONSTRUCTION INDUSTRY

Innovation in Nigeria's construction sector appears aligned with the diffusion of innovation theory, which elucidates adoption patterns about process, product/technological, and business system innovations within the country's construction domain. In Nigeria, consultants are generally referred to as knowledge-based professionals who are employed to provide expert analysis and advice that will enhance decision-making, provide specialized and one-off services, and perform tasks that are not ordinarily available within the departments or agencies of the clients (Ijigah et al., 2012). A study by Ibironke (2004) on innovation in the construction sector in Nigeria suggests that consultants are usually approached and commissioned by clients to provide services relating to the conceptualization, planning, and execution of construction projects. Key consultants in construction encompass architects, quantity surveyors, professional builders, and engineers (civil/structural, electrical, mechanical), who translate client briefs into reality via technical expertise and professional judgement. Nonetheless, consultant performance has reportedly fallen short of client expectations. Cox and Thompson (1997) highlight inefficiencies among construction consultants in project delivery, leading to unmet client needs. Consequent issues plague numerous projects: cost/time overruns, abandonment, structural failures culminating in collapses and substantial losses. Client organisations and stakeholders exert significant pressure for paradigm shifts in construction sector culture/practices to enhance delivery and client satisfaction. Nigeria's construction innovation landscape mirrors these challenges, potentially exhibiting more pronounced manifestations compared to developed nations. Yusof et al. (2010) emphasize the need for innovation amongst construction organisations to confront continuously increasing technological capabilities, changing client requirements, conducting tighter controls over the environmental regulations and quality standards, rising construction costs, increased competition, and other challenges that are associated with the process. However, studies have shown that the key players of the construction industry in Nigeria is slow to adopt new innovative techniques and changes (Ijigah et al., 2012). Furthermore, actors within

the Nigerian construction industry were also rated as having a low disposition towards the adoption of innovative techniques and ideas about changes (Usman et al. 2012). Toole (2010) reaffirms that innovation in the construction industry produces architectural and engineering designs, buildings, industrial and infrastructure developments, procurement and services; moreover, innovation is well embraced by large engineering procurement-construction.

Furthermore, researchers have also indicated that construction industry innovation studies in Nigeria have been scarce and mainly focused on the contracting organizations, with very few paying attention to the consultancy sector (Yusof et al., 2010). Moreover, Arvanitis (2008), in his study on innovation activity in the service industry, concluded that innovation activity within the service sector remains an underexplored area of research, due to a lack of appropriate data at the level of firms. This dynamic pertains to Nigeria's construction sector, notwithstanding the critical roles consultants fulfil in conceptualising, planning, executing, and controlling projects from start to finish – positioning them as potential innovation catalysts in the built environment. Ozorhon et al. (2010) advocate redirecting construction innovation research focus away from industrial/organisational levels (where initiatives are readily established and monitored) towards other potentially impactful areas.

VI. COSTLY CONSTRUCTION INPUTS

The reliance on imported, costly construction materials constrain Nigeria's building industry growth. Despite abundant raw material potential, scarce local production poses a threat to sustainable construction sector development (Ogunlana et al., 1996). Tunji-Olayeni et al. (2012) attribute high material costs to governmental and industry stakeholder shortcomings in harnessing local raw materials, exacerbating foreign exchange challenges.

Paradoxically, Nigeria exports building materials even as farm waste offers viable local alternatives. Ganiron Jr et al. (2017) note significant aggregate components for construction lie within Nigeria's waste systems. Mogbo (2001) and Abiola & Oladele (2000) affirm that building materials profoundly impact Nigeria's construction industry operations. Materials typically account for over 50% of construction costs (Okereke, 2003; Stanley et al., 2014), constituting a major housing delivery impediment. Addressing procurement expenses is critical; innovating farm waste into building materials presents an underexplored opportunity, with preliminary indications of feasibility. Financial constraints compound material cost challenges, contributing to Nigeria's housing shortages. Government and stakeholders must pursue local material development alternatives to mitigate foreign exchange burdens and spur housing delivery. Transforming agricultural waste into construction inputs could alleviate costs; subsequent sections explore farm waste utilisation for sustainable Nigerian construction industry growth.

VII. AGRICULTURAL RESIDUES

Agricultural waste typically denotes by-products of farming activities, distinct from primary

outputs. These include crop residues (stalks, straw, leaves, roots, husks, shells) and animal waste. Sabiiti et al. (2004) highlight agricultural waste's renewability, availability, and virtual costlessness, positioning it as a valuable resource convertible into energy forms (heat, steam, charcoal, methanol, ethanol, biodiesel), animal feed, compost, biogas, and construction materials. Despite this potential, substantial volumes remain underutilized, often dumped or openly burned, precipitating environmental and health hazards in developing nations like Nigeria. United Nations Environment Statistics (1997, cited in Field, Kuczera, & Pont, 2007) link agricultural operations to waste generation encompassing manure, harvest remnants, fertilizer/pesticide runoff impacting soil/water/air. Obi et al. (2016b) define agricultural waste as non-product outputs from raw agricultural processing, compositionally varying by agricultural type, categorical as animal waste, food-processing waste, crop waste, and hazardous/toxic subsets.

Global estimates suggest 140 billion metric tons of annual generation (Agamuthu, 2009), with intensifying agriculture amplifying volumes. Improper disposal, including burning, emits methane, CO₂, and pollutants, contributing to environmental degradation. Sabiiti et al. (2004) and Tumuhairwe et al. (2009) underscore disposal method impacts; burning releases harmful pollutants (carbon monoxide, nitrous oxide, nitrogen dioxide, particulates), fostering acid deposition and health/ecological risks. Valorising agricultural waste as a resource—not discarding—is advisable for nations; collaborative institutional frameworks leveraging conversion technologies are pivotal for harnessing its potential in construction and beyond.

S/N	Ecological Zone	States Involved	Agricultural waste
1	South West	Oyo, Ogun, Ondo, Osun, Ekiti, Lagos	Maize (cub, shaft, brow) rice brow, palm kernel shell and shaft, bagasse, coconuts shell
2	South-South	Edo, Delta, Bayelsa, Rivers, Cross River, Akwa Ibom	Maize straw, palm kernel and coconut shell
3	South East	Anambra, Enugu, Imo, Ebonyi, Abia	Maize straw, palm and coconut shell
4	North Central	Plateau, Benue, Niger, Kogi, Jigawa, Zamfara	Sorghum straw, rice straw, <u>benissed</u> straw, bagasse
5	North West	Kaduna, Kano, Sokoto, Kebbi, Jigawa, Zamfara	Sorghum straw, Millet straw, <u>Beniseed</u> , Bagasse
6	North East	Bauchi, Gombe, Taraba, Yola, Adamawa, Yobe	Bagasse, sorghum straw, millet straw

Table 1: Agricultural Waste Generated in Different Ecological Zones in Nigeria. (source adapted from Ogunwusi. 2014)

VIII. FARM WASTE UTILISATION

Farm waste generation stems from diverse farming activities like horticulture, dairy farming, livestock breeding, grazing, and woodland use ancillary to other agricultural purposes (Obi et al., 2016c). It encompasses on-farm processes including slurry spreading, chemical/waste storage, silage production, and pesticide disposal. Globally, countries categorise farm waste variably via legislation to aid identification.

Such waste can transform into valuable commodities/products for on-farm use or Obi et al. (2016c) note conversion into solid, liquid, gaseous products benefiting users, often cost-effectively due to low production costs. Recent interest spurred innovations like biomass yielding biogas for domestic/commercial power. Agro-processing by-products (animal/plant waste) serve as biogas feedstock. Composting transforms organic waste into fertilisers, improving soil fertility (Amodu et al., 2007), crucial in Africa (including Nigeria) where nutrient scarcity and economic constraints limit inorganic fertiliser access (Brouwer et al., 1998). Composting reduces waste volume, kills pathogens, curbs weed germination, and lessens odour. Products like compost can generate revenue or support on-farm use, aligning with rising organic product demand (e.g., goat meat, maize). Nigeria's agricultural sector, neglected post-oil exploration, sees untapped potential in farm waste innovation for sustainable construction.

IX. FARM WASTE USAGES

Agricultural production waste constitutes 30–60 percent of products intended for human consumption and animal feed, with an additional 30 percent stemming from human and animal waste. Conventional utilisation of crop residues and cattle dung proves inefficient, stripping agricultural lands of vital organic matter and nutrients. Such practices endanger human/animal health and significantly pollute the environment. Alternative valorisation pathways for agricultural waste include composting and animal feed production (Obi et al., 2016a), offering potential improvements over traditional methods. Other valorisation paths are Composting, Animal feed production, and Mushroom culture. Biogas production.

X. BUILDING PROJECTS WORK

Furthermore, in Nigeria, diverse waste streams—from domestic refuse to agricultural residues—pose environmental threats. Within this research scope, scholars have explored converting agricultural waste into valuable outputs. However, an integrated innovation framework harnessing agricultural waste's construction potential remains underexplored. Subsequent sections elucidate agricultural waste's latent opportunities.

A. Case Study: Rice Husk Ash-Based Bricks

A case study of rice husk ash-based bricks in Nigeria illustrates the potential of the proposed framework (Oyenuga et al., 2019). Rice husk ash is a byproduct of rice processing that is capable of being a sustainable alternative to construction materials. By engaging stakeholders, sharing knowledge, and collaborating on problem-solving,

researchers and industry professionals can develop and commercialize rice husk ash-based bricks that are durable, sustainable, and cost-effective.



Figure 1: A building made of Rice Husk-based bricks.



Figure 2: Sample of Rice Husk-based Bricks.

B. The proposed framework consists of four key components:

Stakeholder Engagement: Identify and engage relevant stakeholders, including farmers, researchers, policymakers, and industry professionals, to ensure that the framework is responsive to the needs of all parties involved (Etzkowitz & Leydesdorff, 2000).

Knowledge Sharing: Establish a knowledge-sharing platform to facilitate the exchange of information, expertise, and best practices among stakeholders (Nonaka & Takeuchi, 1995).

Collaborative Problem-Solving: Foster collaboration among stakeholders to identify and address challenges, develop new products and processes, and improve existing ones (Gray, 1989).

Innovation Support: Provide support for innovation, including funding, training, and infrastructure,

to enable the development and commercialization of Farm waste-based building materials (Acs et al., 2009).

XI. CONCLUSION

Developing a Cooperative Innovation Model is pivotal for harnessing agricultural waste as a construction material in Nigeria. Through stakeholder engagement, knowledge sharing, and joint problem-solving, Nigeria can tap into agricultural waste's potential, fostering sustainability in its construction sector.

Instituting a cooperative innovation management structure would facilitate the development and deployment of agricultural waste-based building materials. Such collaboration enables Nigeria to unlock agro-waste opportunities, driving sustainable construction industry growth.

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