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Research paper

A Feasible Circularity Model for Construction Wood Wastes in Developing Countries: The Case of Kenya and Nigeria

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Abstract

As the population of Africa is expected to reach 2.4 billion by 2050, construction activities are also expected to increase due to urbanization. This would create an increase in the demand for more material and the generation of more construction wastes which largely constitute concrete, reinforcement steel, and wood wastes. In Nigeria, the management of construction waste is not sustainable enough, likewise in Kenya. Construction sector remains a major contributor to solid waste disposal. The approach of circularity in the construction sector presents an alternative for preparing for re-reuse and recycling of valuable construction wood wastes. Creating more business opportunities for local craftsmen and second-hand material sellers. However, the lack of a circularity model of practice for construction activities remains a challenge among many others. The objective of this paper is to develop a feasible circular economy model for construction wood Waste for Kenya and Nigeria, of which the paper first reviewed the barriers and potentials of circular economy in the construction sector of these two countries, then reviewed relative literatures on organizational or business models of circular economy in construction sector and other sectors, to understand and re-interpret an appropriate circularity models feasible for construction wood waste in Kenya and Nigeria. Secondly a structured questionnaire survey was carried out with stakeholders from both countries to access their input on the feasibility of the developed model. The stakeholders' survey reveals that 69 percent agreed that the model is feasible in Kenya, while 38.5 percent agreed that the model is feasible in Nigeria, another 38.5 percent agreed the model is fairly feasible in Nigeria. The stakeholders also attested to other measures that would improve the proposed construction wood waste circularity model including early-stage design decisions, involvement of government regulations, introduction of Building Information Modelling (BIM), and introduction of independent warehouse storage facilities.

Keywords: Construction Sector · Circularity Model · Feasibility · Construction Wood Wastes · Developing Countries

1. INTRODUCTION

The global transition from a linear to circular economy especially in the construction sector, sparks the need for sustainability in construction practice. The adaptation of circularity strategies in the construction sector would help mitigate the negative impact of construction wastes and offer alternatives to the management of construction or demolition wastes (Talamo et al., 2022). This is correlated to the fact that the construction sector accounts for more than a third of the globally generated solid wastes (Jahan et al., 2022). In developing countries, construction waste constitutes a large portion of solid waste disposed in landfills (Soezer, 2016). In the Kenyan city of Nairobi, about 3207 tonnes of solid waste are generated daily (Climate-KIC, 2024), while in the Nigerian city of Lagos, about 13,000 tonnes of municipal waste are disposed of in the landfills across the city, which is expected to increase due the annual population increase (Aboginije et al., 2021). The composition of these construction and demolition wastes in landfills

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are largely concrete, reinforcement steel, and wood. Wood waste notably contribute to about 20 to 30 percent global stream of construction and demolition waste (Jahan et al., 2022). Moreover, the global demand for wood products continues to increase due to rapid population growth and the increase in construction activities, especially in developing countries (Unai et al., 2021).

As a multi-purpose material, wastes from wood can be easily re-worked manually or repurposed into other useful products by local craftsmen especially in developing countries with limited technological advancements (Olusola, 2024), unlike construction waste like concrete that require industrial remanufacturing. However, technological advancement or industrial recycling is also crucial for effective construction wood waste management due to the high demand of wood products for construction in developing countries (Olusola, 2024). This high demand of wood contributes to the loss of certain species of timber in Nigeria (Olusola, 2024) and contributes to the high price of timber products in Kenya due to the ban on forest logging (Ministry of Industrialisation and Enterprise Development, 2015), whereas the vast majority of construction wood waste are not properly utilised, contributing to further environmental impacts as a result of improper management (Owoyemi et al., 2016). However, an improved introduction of circular economy approaches, through the adaptation of a suitable circular economy model, by relative construction sector stakeholders can enable the proper management of construction wood wastes (Desmond & Asamba, 2019). Through a circularity model of stakeholder's network, linking local craftsmen, waste collectors, small and medium enterprises (SMEs), contractors, wood waste recyclers and remanufacturers. Material supply chain and information flow can be more effective for construction wood waste reuse, repurpose, recycle, or remanufacture (Bello et al., 2024). This kind of practise can enable the creation of job opportunities, economic activities, and reduction of landfill disposals (Owoyemi et al., 2016). An example of circularity wood waste stakeholders' network is the Rilegno consortium in Italy, operating with a defined circularity model (Rilegno, 2024). However, an appropriate circularity model can also be tailored to suit a developing country's context.

The developing countries context adopted for this research are Kenya and Nigeria. These two developing countries in Africa, have experienced increase in construction projects and investable increase in construction waste generated (Unai et al., 2021). While the West African region have the highest number of recorded construction projects, Nigeria in West Africa has the highest number of construction projects (Marais & Ntsoann, 2021). Comparatively, while Kenya has the second highest number of construction project in the East African region (Marais & Ntsoann, 2021), Kenya has the highest number of reported constructions related circular economy initiatives in Africa (GRID-Arendal, 2021). Which will enable the research on the insight of construction wood waste utilisation and the feasibility of a proposed circularity model in these two developing countries. In Kenya the introduction of the revised building code in February 2023, makes it possible to use circular materials. The new building code will now allow the reuse of construction wastes through recycling and repurposing, if it meets the required standard (Wahome, 2023). This can enable more opportunities for the local craftsmen work force in Kenya (Jua-kali) by repurposing wood wastes from construction sources. This approach can ultimately enable the reduction of wood wastes disposed in landfills (Sibanda et al., 2017). While in Nigeria the environmental challenges of disposed wood wastes in landfills, water bodies, and open air burning of wood wastes is a drive to proper management of construction wood wastes (Olusola, 2024). The strategy of proper construction wood waste collection, through local collectors, to craftsmen for repurposing with the involvement of small and medium enterprises (SMEs) construction companies can enable further management of possible construction wood wastes (Aboginije et al., 2021). However, since most developing countries lack improper solid waste management (Owoyemi et al., 2016) this study may be applicable to other developing countries in Africa.

Reviewed literatures in this study reveals a research gap of appropriate strategies or attributes of circular economy model that will guide the proper management of construction wood waste. With this opportunity to make value from construction wood wastes through reusing, recycling, and repurposing. This study aimed to develop a circular economy model, that will enable a sustainable management of construction wood waste in Kenya and Nigeria. This would involve managing the wood wastes through a feasible model of circularity that would create economic, environmental, and social benefits, by involving local craftsmen, second-hand building material sellers, and waste collectors. By adopting Re-NeTA (Re-manufacturing Network for Tertiary Architecture) approach for achieving a circularity model which involved the procedures of outlining key features of circular models from other sectors, then adjusting and respecifying it, to a more feasible attribute for a construction wood waste model with the inputs of related stakeholders (Talamo et al., 2022).

Further chapters of this study present the literature review which include the barriers and potentials of reusing construction wood waste in Kenya and Nigeria, attributes of the research methodology, identified research gaps, analysis of circularity model features, proposed circularity model, discussion of stakeholder response on the proposed model, conclusion and recommendation. Furthermore, in line with the study context of developing countries, this study outlines three research questions. These questions are:

- Q1. What will be a feasible circularity model adaptable for construction wood waste?
- Q2. How feasible is the circularity model in the context of either Kenya or Nigeria?
- Q3. What other measures would improve the proposed circularity model?

2. LITERATURE REVIEW

2.1 Potentials and Barriers of Circular Economy in the Kenyan and Nigerian Construction Sector

The concept of circular economy in the African Construction sector is relatively new. Though there are many potentials for boosting construction related circular activities both in the case of Kenya and Nigeria, there are also many barriers to it. In Kenya organization like the Kenyan Green Building Society (KGBS) remain a major driver to the awareness campaign of Circularity in the Built Environment. The presence of local craftsmen activities (Jua kali) and second-hand material sellers provide an opportunity to boost the current practice by interacting with established construction companies for easy flow of construction/demolition wastes (CDW) as second-hand material. In Nigeria, the trend of Small and Medium Enterprises (SMEs) construction firms presents an opportunity to boost their business practice with secondary materials coming from construction or demolition wastes or recycled materials (John et al., 2023). Like KGBS, Green Building Council of Nigeria (GCBN) is also leading in the campaign of awareness on circular economy practice in the construction sector, this is attributed to the social barriers on lack of awareness among construction stakeholders in both Kenya and Nigeria. Bello et al., (2024) revealed that a well-defined circular economy model suitable for the Nigerian context as hinderance to circular economy implementation. Other barriers include economic barriers of lack of demand for recycled and reused materials from large construction companies (Charef et al., 2021), and organizational barriers of lack of interest or concern from organizations and Stakeholders (Jonathan, 2023). However, the potential of Informal craftsmen activities, second-hand material sellers, and SMEs construction firms could be vital for activating a Circularity model in these African countries creating more networks with large construction firms, material suppliers, and collectors of construction and demolition wastes (Idris & Bello, 2023).

2.2 Issues of Construction/Demolition Waste (CDW), Emphasis on Wood Wastes

Construction waste in Africa is expected to reach 516 million tonnes by 2050 of which 90 percent of the waste will likely be deposited in landfills (Footprints Africa report, 2022). The composition of these CDW wastes in the landfills, illustrated in figure 1, as reported by Aboginije et al., (2021) consists of concrete, plywood, reinforcement steels, plastics, and packaging materials with concrete, steel, and wood, with wood waste having a higher range of 15 – 20 percent after concrete. The unstainable traits of construction waste management need to be upgraded. This upgrade would also involve policy implementations, and eliminating waste by using them as secondary materials, and promoting the use of building reusable materials (Jonathan, 2024). The emphasis on wood waste as a secondary material or as reusable building material should be driven by the large volume of disposed wood waste in landfills, its benefit to local craftsmen (furniture makers and carpenters), the increasing cost of wood especially in Kenya with the ongoing timber deficit (Ministry of Industrialisation and Enterprise Development, 2015), the global increase in the demand of wood due to the ever-growing population especially in developing countries or mega-city like Lagos and the environmental challenges of inland water ways blockage with disposed woods (Owoyemi et al., 2016). The physical forms of these wood wastes include soft woodcuts, hardwood wastes, mixed woods, sawdust, wood shaving, and off-cuts wood wastes which can be recycled, reused, or repurposed. These initiatives of reusing wood wastes would need a feasible model of practice involving all stakeholders, through the supply chain allowing for information flow from the construction/demolition projects through the collectors to remanufacturing and back to construction projects or other destinations

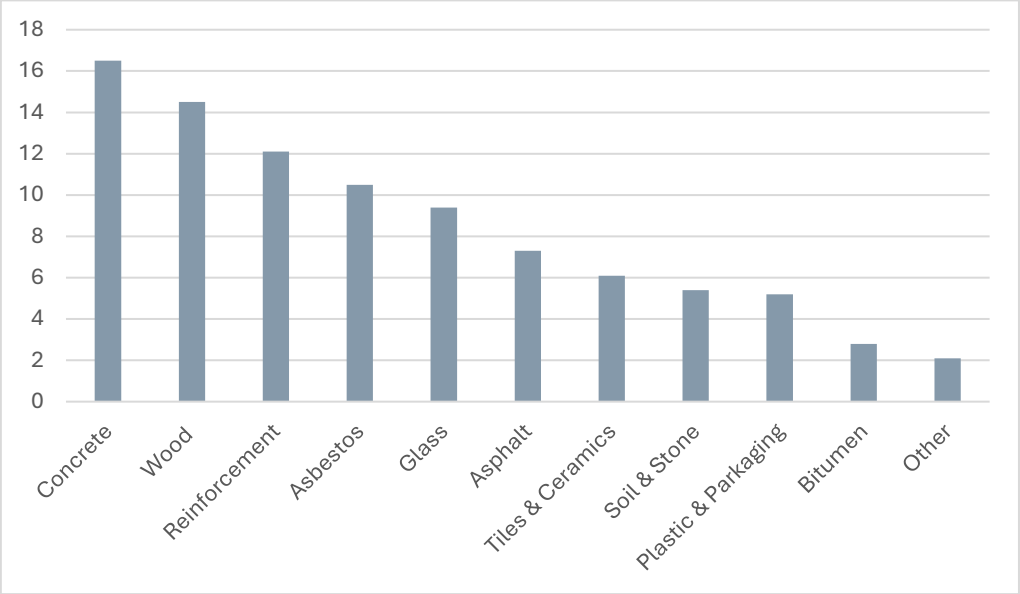

Figure 1. Composition of Disposed Construction Waste in Lagos, Nigeria, (Aboginije et al., 2021)

2.3 Status, Potentials and Barriers to Reusing Construction Wood Waste in Kenya

The major barriers include the old Building Code of 1968 that lacks the provision for reusing construction waste (Sagini, 2022), lack of proper waste management systems and negative attitudes and unwillingness of contractors to re-use construction waste that results to construction wood waste disposal in landfill (Sibanda et al., 2017). However, positive potentials include the revision of the old building code in 2023 that now include the provision to reuse construction waste (Wahome, 2023), shortage in local wood supply for construction activities as an advantage, the opportunity presented by local craftsmen Jua-kali in upcycling or repurposing construction wood wastes (Waweru, 2017), and the potentials of new business through circularity (Muriithi & Ngare, 2023) with the existing e-commerce online vendor that can be used to market valuable construction wood wastes.

The Building Code is the primary legislation regulating all construction matters in Kenya. In July 2024, the National Construction Authority (NCA) launched the National Building Code 2024, The new code will take effect in February 2025, one year after publication replacing the repealed Building Code of 1968 (National Construction Authority, 2024). According to Erastus & Wuchuan, (2014) many of the challenges facing the construction sector in Kenya today is the failure of the code's regulations to reflect the realities of the Kenyan building industry and its evolution over the years. In addition to this, section 33 of the code states that "*Unless the council otherwise agrees, no second-hand material shall be used",* (Sagini, 2022), placing an indiscriminate blanket ban on used construction materials. This has been a major impediment to developing circularity practices in Kenya's construction sector for decades. However, the new National Building Code 2024 is anticipated to usher in a new era of sustainable practices in the construction sector in Kenya. Section 59 of the new code makes a provision for re-use of materials, on condition, the material meets the requirements as per the relevant standards (Wahome, 2023). Furthermore, in Kenya lack of proper waste management systems, inadequate guidelines, regulations, enforcement, lack of interest by stakeholders and lack of circular economy models or concepts are hinderances to effective management of waste including the construction sector (Desmond & Asamba, 2019) and (Turing, 2021). The lack of interest by construction stakeholders has been revealed by several studies showing that negative perceptions of used construction materials affect people's willingness to reuse and recycle them, expressing concerns over quality, structural integrity, and fear of contamination of the materials (Shooshtarian et al., 2020); (Rakhshan et al., 2020);(Citraningrum et al., 2023) and (Jonathan, 2024).

However, with the initiative of the Affordable Housing Act, 2024, the Kenyan government endeavors to bridge the gap in demand for housing in Kenya. This initiative to build 500,000 housing units presents a great opportunity for the government to promote sustainable construction waste management, especially used wood waste in the face of a shortage of wood products in the country. According to (Collins, 2020) Kenya is facing an acute shortage of wood, as demand continues to rise due to the government's ban on logging in public forests in 2018. The ban was necessitated by negative environmental impacts experienced because

of the depletion of the country's forest reserves by illegal logging, charcoal burning and clearing forest land for farming. To meet the future demand, Kenya must plant 200,000 hectares for the next 10 years (Collins, 2020). This has resulted in overreliance on imports to meet the demand, especially for industrial wood. The timber crisis presents an opportunity to advocate more sustainable practices in construction wood waste management in the country. The absence of proper construction waste recovery systems in Kenya have also created room for burgeoning informal physical and online markets for second-hand construction materials. Nairobi hosts several streets known for items, where reclaimed timber, steel, iron sheets, bathroom fittings and furniture can be found. An intricate referral network of middlemen and vendors also links the sources of these materials with potential buyers. In addition to this, online platforms can also play a big role in this informal system. Individual vendors, dealers, and businesses use various social media and e-commerce platforms to market their wares and connect with potential buyers (Statista, 2024). The success of e-commerce in trading a diverse range of goods in Kenya indicates huge untapped potential for the growth of online construction waste recovery platforms. According to a report by Visa, Kenya ranked third in Africa in total volume of e-commerce in 2019 and 2020. The E-commerce revenues were primarily drawn from entertainment, household goods, Food, electronics, personal care products as well as fashion, and the revenues are expected to continue with a positive annual average growth of 16.4% by 2025 (Statista, 2024).

As upcycling is an important component of circularity in construction waste recovery, Kenya is home to a booming informal trade and artisan industry popularly known as Jua-kali (Jonathan, 2023). The Jua-kali industry comprises skilled carpenters, metalwork welders and fabricators, automotive mechanics, and roadside traders. Renowned for manufacturing and cost-friendly inventions, the Jua-kali sector provides the workforce necessary to bolster the recovery of construction waste wood. According to the Kenyan Bureau of Statistics, the informal sector creates over 90.7% of new jobs in Kenya, most of which are in the Jua-kali sector (Munro et al., 2022). In the recent years, sustainable practices in the construction sector have continued to grow, culminating in several progressive initiatives that promote construction waste recovery, notably the formation of the Kenya Green Building Society (KGBS) in 2012, to promote sustainable building practices in the country. Through KGBS, as part of the requirement for green building certification under the Green Star system, developers are required to ensure efficient resource utilization through the minimization of construction waste right from the design stage by material choice materials and designing for deconstruction, to demonstrate waste management and recovery strategies throughout the construction period of the project (Kenya Green Building Society, 2024).

2.4 Impact, Potentials and Barriers to Construction Wood Waste in Nigeria

In these contemporary times wood is a valuable material in the construction sector same in the Nigeria construction sector (Olusola, 2024) but inefficient management of large wood waste deposit presents many environmental and socio-economic challenges, with existing barriers and potentials of reusing this construction wood wastes. In the Nigerian city of Lagos with a projected population of 21 million people (Aboginije et al., 2021), there is growing increase in construction activities, of which construction wood waste has been on increase due this increases in construction activities, lack of proper wood waste management initiatives and lack of wood waste processing factories etc (Akhator et al., 2017).

Environmental challenges associated with construction wood wates and other wood wastes in Nigeria include air pollution with toxic air because of burnt wood wastes, inland water ways contamination/blockage and land disposals as pollutants (Oluoti et al., 2014). These practise of dumping construction wood wastes in landfills, dumping wood wastes in water ways and burning wood wastes is a common practise in most developing countries in Africa (Owoyemi et al., 2016). A study by Owoyemi et al., (2016) revealed that wood wastes from construction and demolition activities with paints, that can be recycled often end up in open air burning, which leads to several health challenges to nearby communities. While about 44-60% of wood waste from sawmills industry are unutilised in Oyo state Nigeria (Kanu et al., 2024), the exact figure of wood waste coming from the construction remains unidentified, moreover since it cost money for construction companies in Nigeria to dump construction wastes in Landfills (Owoyemi et al., 2016), it becomes important to examine the existing barriers and the potentials of utilising wood wastes coming from construction and demolition activities.

The barriers of ineffective waste management policies, lack of legal structures and policy frameworks in the city of Lagos is common across cities in Nigeria, hindering effective management of construction wood wastes, a survey by Aboginije et al., (2021), respondents reveal that basic off-site preparation of construction wastes are carried out in Nigeria, which is not sufficient for effective management of construction waste generated. A study by Bello et al., (2023) identified government regulations and provision of incentives as drivers of circular economy in Nigeria construction industry, of which poor utilization of wood waste in Nigeria can also be linked to lack of incentives for wood waste utilization, lack of information on the economic returns of re-using wood waste, and lack of technical know-how on wood waste processing, re-purposing and reusing (Akhator et al., 2017).

There are numerous potentials to effective management of Construction wood wastes in Nigeria, which can stimulate domestic economic development, prevent environmental deterioration and contribute to effective solid waste management strategies (Akhator et al., 2017). These potentials include boosting the activities of informal private sector practitioners involved in construction waste collection (Aboginije et al., 2021) through a proper strategy for wood waste collection in collaboration with construction companies, supported by government regulations. Small and medium enterprises (SMEs) involved in construction activities (John et al., 2023), construction material procurements can create more job opportunities and economic benefits by further making use of repurposed wood products, refurbished by local craftsmen who uses materials coming from construction wood wastes.

A summarised overview of the major literatures of the study context are provided in table 1, with identified research gaps, that will guide the contribution of this study.

Table 1. Overview of Major Literatures Reviewed and Identified Research Gaps

Literatures	Identified research gaps
(Idris & Bello, 2023)	Possible barriers and potentials of implementing circular economy strategies in the construction sector. Synergies of network or bringing together relative stakeholders in the construction sector.
(Aboginije et al., 2021)	The study did not provide further attributes on any specific construction waste management despite the large tone of concrete and wood disposed in landfills.
(Muriithi & Ngare, 2023)	The paper outlines circularity business potentials but lack focus on the construction sector and circularity of construction wastes.
(Sibanda et al., 2017)	The authors outlined the present solid waste management system, the stakeholders involved but no proposed approach or model on the improving the current solid waste management system.
(Waweru, 2017)	The research did not consider wood wastes coming from other sectors i.e. construction sector and how it could contribute to the upcycling of furniture products.
(Akhator et al., 2017).	The research makes efforts on the overview of wood wastes from different sectors, but no appropriate strategies on how to manage these wood wastes and prevent the menace from its disposal.
(Bello et al., 2024)	The research outlines barriers and potentials of Circular Economy in the construction sector of developing countries including Nigeria, without specific consideration to a particular construction waste.
(Olusola, 2024)	The study was limited to wood waste from wood manufacturing companies without broader interaction with other sectors like the down-cycling or up-cycling of wood waste from construction sectors.
(John et al., 2023)	The study did not provide a model or narrative by which Small and Medium Enterprises (SMEs) in the construction sector, can interact for a collective shared benefit through circularity.
(Bello et al., 2023)	The study only provided theoretical attributes for circular economy implementation in the Nigerian construction sector, the research did not consider other African countries, the study provided an overview assessment without a consideration on how it will affect specific construction waste supply flow.
(Desmond & Asamba, 2019)	The research only provides an overview of Circular Economy policies and practices in Kenya and South Africa, without appropriate business models feasible in the African context.
(Turing, 2021)	The research only suggested the need for a circular economy concept for social, environmental and economic benefits and the need for the concept to be realistic for the context of Kenya.

2.5 Organizational / Business Model (Circularity Model) for the Construction Sector

The transitions to a Circular Economy in the construction sector would need a paradigm shift from the linear practise to a circular practice, of which it would be important to have a model of practice relative to a business and organizational model of practice for the stakeholders and practitioners involved (Jayakodi et al., 2024). A traditional business model is mainly focused on economic interest, while a circularity model would need to consider environmental, and social interests (Ruiter et al., 2022). A circular economy model can enable organizations to meet their target mission for sustainability demands, especially in the construction sector in developing countries with increasing construction activities. The ongoing activities of make-use-dispose strategies of solid waste disposed in landfills, have negatively contributed to environmental impacts , to mitigate this, the strategies of down-cycling and upcycling of resulting valuable construction and demolition wastes through recycling, re-manufacturing, reuse, and preparation for reuse (re-purposing, re-pairing) would be required through a structured model of circularity with all involved stakeholders creating more economic benefits, social benefits, and environmental benefits of avoiding landfill disposals (Talamo et al., 2022). With the construction sector contributing to more than a third of the global deposit of solid waste, closing this loop of landfill disposal, and extending the lifespan of valuable construction wastes, a well-structured

model of circularity in the supply chain would be required just like the well-established practice of circularity in other sectors such as aerospace, electronics, machinery, and rail re-manufacturing strategies (Talamo et al., 2022). With Kenya and Nigeria, been strong economic hubs of East and West Africa and their booming real estate and construction activities, a well-structured model of circularity is needed to achieve more sustainable benefits from the construction/demolition wastes, specifically from wood wastes that offer an easy form of re-working by local craftsmen or companies.
To achieve a feasible form of circular economy model workable for the context of Kenya and Nigeria, this paper adopts the Re-NeTA (Re-manufacturing Networks for Tertiary Architecture) (Talamo et al., 2022) approach to proposing a Circular Economy Model for wood wastes coming construction and demolition activities.

This Re-NeTA procedure steps include:

1. To identify which aspect of the building construction sector is the most promising and able to offer products to be potentially re-worked (remanufactured, recycled, repaired, re-purposed).
2. Identify the paradigm shift that has allowed other sectors to leap (progress) towards circular processes.
3. Outline the key features of circularity models already in use in other sectors and learn from the models and adjust necessary features to the construction sector model with the support of the stakeholders subject to their response.
4. Develop a new circularity model feasible for the Construction sector of Kenya and Nigeria suitable for the informal practice and existing companies' practices vetted by stakeholders and validated in the field.

The aspect of the building construction sector to be taken into consideration in this case is the construction and demolition wastes focusing on wood waste. With the presence of local craftsmen in both Kenya and Nigeria, that can repurpose these wood wastes. From the second and third procedures of Re-NeTA, this study presents the analyses of three circularity model case studies, from the construction sector, carpet manufacturing industry, and wood products manufacturing industries. Identifying the major (paradigm shift) drivers for adopting circularity by these companies, identifying their key features based on the Re-NeTA framework for re-manufacturing, learning from these features, and outlining possible features for a proposed circularity model feasible for the contexts of Kenya or Nigeria. The results of these analyses are shown in figures 2,3,4 and tables 2,3 and 4.

2.5.1 Case Study One: Company A, Brescia, Italy (Fontana, 2024).

Company sector: Exhibition industry (Carpet covering).
Products (Re-manufactured or manufactured): Rugs, synthetic grasses, fabrics.
Company magnitude: Production potential of over 15 million m2 in 30 countries around in the world.
Drivers to adopting circularity: Recycling of carpets after exhibition projects for Company A was born due to: Modern consumers increasingly aware of environmental and social issues; More efficient use of resources, and waste reduction; Current and future regulations will be increasingly stricter on sustainability; Employees are increasingly supportive of working for companies that embrace sustainable values; Orientation towards sustainability can stimulate innovation within the company.

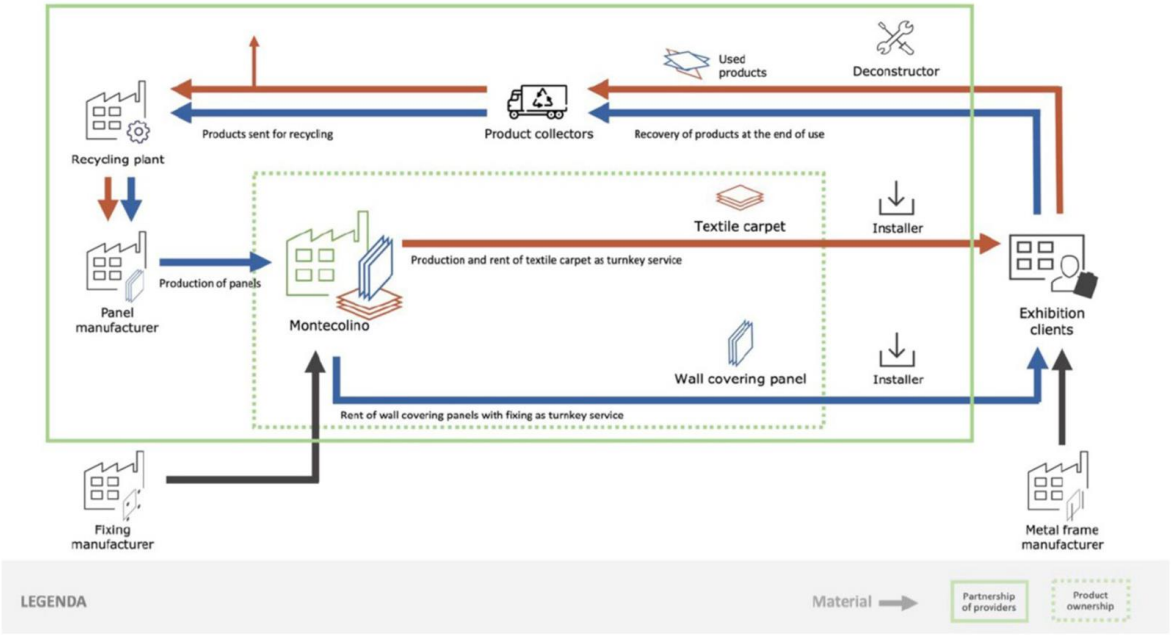

Figure 2. Company A Circular Economy Model: Introducing New Recyclable Products That Are Produced Using Secondary Raw Materials Coming From Recycled Carpets (Fontana, 2024)

Table 2. Case Study 1 (CS1) Key Features

Key Features		Possible configurations		CS 1
A	Original product design	**A1**	**Product designed for re-manufacturing**	
		A2	Products not designed for re-manufacturing	
		A3	Product not designed for re-manufacturing but with facilitating features	
B	Product procurement	B1	Surcharge-based mechanism	
		B2	Buy-back mechanism	
		B3	Direct order mechanism	
		B4	Service contact mechanism	
		B5	**Leasing mechanism**	
C	Product collection	C1	Enabled by collectors' activity	
		C2	Performed autonomously by the re-manufacturer	
		C3	**Hybrid solutions**	
D	Re-manufacturing actors	D1	Original Equipment Re-manufacturer	
		D2	**Contracted Re-manufacturer**	
		D3	Independent Re-manufacturer	
E	Re-manufactured product design	**E1**	**Product re-designed for re-manufacturer**	
		E2	Product not re-designed for re-manufacturing but with facilitating facilities	
		E3	Product not re-designed for re-manufacturing	
F	Product-service distribution	F1	With a partner intermediation	
		F2	With a dealer intermediation	
		F3	**Performed autonomously by re-manufacturers**	
G	Product Ownership	G1	Ownership is transferred to the customer	
		G2	**Ownership is retained by the provider**	
		G3	Ownership is transferred to the customer with provider extended responsibilities.	
H	Revenue system	H1	Traditional single payment	
		H2	Deposit-based single payment (with surcharge)	
		H3	**Performance payment (Pay-per-use, Pay-per-period)**	
I	Market destination and segment	**I1**	**Same market destination and segment of the original product**	
		I2	Same market destination as the original product but a different market segment	
		I3	Different market destination from the original product	

The Company A circularity model offers products for rent for exhibition projects, which are collected and recycled for manufacturing for new exhibition carpet products. The products are designed and manufactured to be recycled from the early stage, thereby offering environmental benefits by using them as secondary raw materials.

2.5.2 Case Study Two: Company B, Milan, Italy (Pizzocchero, 2024) (REC, 2024).

Company sector: Construction Sector.
Products (Services): Construction/Demolition waste collection and recycling
Company magnitude: Consortium with the Governance Committee, Technical Committee, and Member companies.
Drivers to adopting circularity: REC, tends to contribute to the objectives of a circular economy in the construction sector; offering support for recycling and dissemination and sale of quality recycled materials; and reducing the dispersion of construction and demolition waste.

Figure 3. REC Circularity Model for Building Material Wastepaper Bags (Pizzocchero, 2024)

Table 3. Case Study 2 (CS2) Key Features

Key Features		**Possible configurations**		**CS 2**
A	Original product design	A1	Product designed for re-manufacturing	
		A2	Products not designed for re-manufacturing	
		A3	**Product not designed for re-manufacturing but with facilitating features**	
B	Product procurement	B1	Surcharge-based mechanism	
		B2	**Buy-back mechanism**	
		B3	Direct order mechanism	
		B4	Service contact mechanism	
		B5	Leasing mechanism	
C	Product collection	C1	Enabled by collectors' activity	
		C2	Performed autonomously by the re-manufacturer	
		C3	**Hybrid solutions**	
D	Re-manufacturing actors	**D1**	**Original Equipment Re-manufacturer**	
		D2	Contracted Re-manufacturer	
		D3	Independent Re-manufacturer	
E	Re-manufactured product design	E1	Product re-designed for re-manufacturer	
		E2	**Product not re-designed for re-manufacturing but with facilitating facilities**	
		E3	Product not re-designed for re-manufacturing	
F	Product-service distribution	F1	With a partner intermediation	
		F2	**With a dealer intermediation**	
		F3	Performed autonomously by re-manufacturers	
G	Product Ownership	**G1**	**Ownership is transferred to the customer**	
		G2	Ownership is retained by the provider	
		G3	Ownership is transferred to the customer with provider extended responsibilities.	
H	Revenue system	**H1**	**Traditional single payment**	
		H2	Deposit-based single payment (with surcharge)	
		H3	Performance payment (Pay-per-use, Pay-per-period)	
I	Market destination and segment	**I1**	**Same market destination and segment of the original product**	
		I2	Same market destination as the original product but a different market segment	
		I3	Different market destination from the original product	

The building material paper bag circularity model by REC is a consortium scheme with all stakeholders involved in the process. Partner members of REC, makes the process more coordinated and easing the recovery of material bag construction wastes.

2.5.3 Case Study Three: Company C, Melbourne, Australia (De Vass et al., 2023)

Company sector: Manufacturing Sector.
Products: The Company specializes in upcycling wood waste from construction, and retail companies into wood packages, palettes, crates, and boxes.
Company magnitude: The company generates 6 million AU$ with 75 employees.
Drivers to adopting circularity: Market demand for environmentally friendly products, latest changes in government policies, new government support grants, and the founders' values and passion for sustainability.

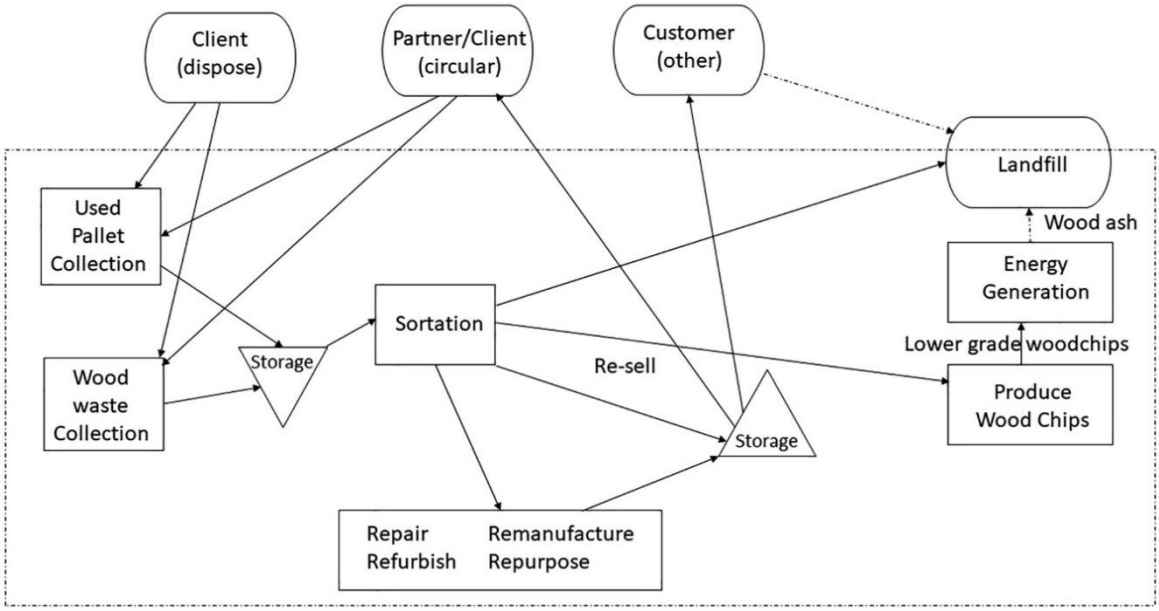

Figure 4. Company C, Circularity Model of Upcycling Wood Wastes into Valuable Objects (De Vass et al., 2023)

Table 4. Case Study 3 (CS3) Key Features

Key Features		**Possible configurations**		**CS 3**
A	Original product design	A1	Product designed for re-manufacturing	
		A2	**Products not designed for re-manufacturing**	
		A3	Product not designed for re-manufacturing but with facilitating features	
B	Product procurement	B1	Surcharge-based mechanism	
		B2	**Buy-back mechanism**	
		B3	Direct order mechanism	
		B4	Service contact mechanism	
		B5	Leasing mechanism	
C	Product collection	C1	Enabled by collectors' activity	
		C2	Performed autonomously by the re-manufacturer	
		C3	**Hybrid solutions**	
D	Re-manufacturing actors	D1	Original Equipment Re-manufacturer	
		D2	Contracted Re-manufacturer	
		D3	**Independent Re-manufacturer**	
E	Re-manufactured product design	E1	Product re-designed for re-manufacturer	
		E2	**Product not re-designed for re-manufacturing but with facilitating facilities**	

		E3	Product not re-designed for re-manufacturing	
F	Product-service distribution	F1	With a partner intermediation	
		F2	**With a dealer intermediation**	
		F3	Performed autonomously by re-manufacturers	
G	Product Ownership	**G1**	**Ownership is transferred to the customer**	
		G2	Ownership is retained by the provider	
		G3	Ownership is transferred to the customer with provider extended responsibilities.	
H	Revenue system	**H1**	**Traditional single payment**	
		H2	Deposit-based single payment (with surcharge)	
		H3	Performance payment (Pay-per-use, Pay-per-period)	
I	Market destination and segment	**I1**	**Same market destination and segment of the original product**	
		I2	Same market destination as the original product but a different market segment	
		I3	**Different market destination from the original product**	

The model of the above Melbourne wood manufacturing company shows the company's commitment to circularity. Involves all necessary stakeholders including transporters, and construction companies taking off potential landfill deposits of construction wood waste that could end up in the Landfill.

3. METHODOLOGY

This study involves the use of mixed methods, which comprises the use of qualitative and quantitative methodologies. This is supported by similar studies carried out by (Akhator et al., 2017); (Aboginije et al., 2021) and (Idris & Bello, 2023). Qualitative methods were used for the literature review of journals, reports and government publications on the research theme, this data guided the research objectives and research questions through the identified research gaps. Existing circularity models were analysed based on Re-NeTA (Re-manufacturing Networks for Tertiary Architecture) (Talamo et al., 2022) procedures that guided the development of a proposed circularity model, also supported with oral interview from construction sector stakeholders in Kenya and Nigeria. The quantitative aspect is given by the feasibility assessment of the developed circularity model through a structured survey questionnaire. The Survey questions were based on 4-5 Likert scale to obtain stakeholders responses on the developed circularity model. The survey questions were distributed virtually using google forms to construction sector practitioners in Kenya and Nigeria, particularly members of Kenyan Green Building Society (KGBS) and Green Building Council of Nigeria (GBCN). These construction sector practitioners include architects, builders, civil/structural engineers, project managers, researchers, real estate developers, landscape architects, and electrical engineers. Their response on the proposed model of circularity guided the research results and discussion in answering the research questions.

These adopted methodologies can be categorised into four stages. The first stage involves a literature review from previous authors on the research topic, outlying their contributions and possible research gaps as outlined in table 1. The second stage involves adopting the Re-NeTA (Re-manufacturing Networks for Tertiary Architecture) (Talamo et al., 2022) approaches of examining and outlining the key features of circularity models already in use in other sectors. Thirdly developing a new model of circularity for construction wood waste supported by insights from the literature review, interviewed stakeholders from Kenya and Nigeria. The fourth stage involves the validation of the feasibility of the new model shared with construction sector stakeholders from Kenya and Nigeria, using a structured questionnaire.

The structured questionnaire involves the following key questions (a) How would you rate the feasibility (possibility) of the structured way of reusing construction/renovation/demolition wood waste in your country (city) as illustrated in the above model scheme image? (b) What other measures would you suggest in improving this Circular Economy model for construction wood waste illustrated above in your country (city) of practise? (c) Do you think Circular Economy practise could improve proper management to construction wood wastes? (d) What could be the possible benefit of wood waste output

through circular economy? (e) What challenges could affect the achievement of this Circularity model for construction wood waste?

4. PROPOSED CIRCULARITY MODEL

4.1 Circularity Model for Construction Wood Wastes

The proposed circularity model focuses on valuable wood wastes generated during construction and demolition projects. In the context of Kenya and Nigeria considering that the notion of Circular economy is relatively new in these countries, 69 percent of the research stakeholders review agreed that the Circular Economy is quite new in Kenya and 46 percent agreed it's new in Nigeria. Therefore, the Model is to be simplified and involve the active key players which include the local second-material sellers and local craftsmen. Creating a business network with established construction companies, and wood product manufacturers or recyclers. The illustration in Figure 5 shows the possible material flow of wood waste from construction projects; higher grade hardwood and softwood off-cuts can be retrieved by local craftsmen and repurposed (upcycling) into other wood products while lower-grade wood off-cuts like sawdust, and wood shaving, off-cuts can be recycled (downcycling) and used for remanufacturing of other products. The new wood products can be reused in construction projects and other destinations like furniture products.

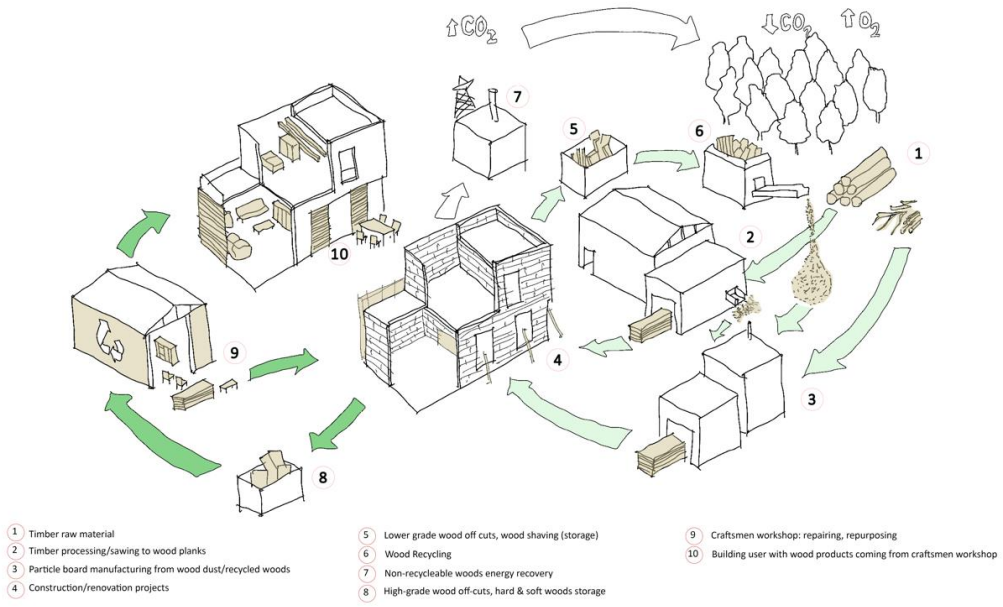

Figure 5. Graphic illustration for the proposed model material flow. Adapted from Bruno Seve scheme (ArcDaily Editorial Team, 2019).

The Proposed Model in Figure 6 can be adopted by Construction companies to define the material flow and business narratives of their possible wood wastes. It can also be adopted and refined by wood product manufacturers to specify the material flow and business narratives of their secondary raw materials coming from wood wastes.

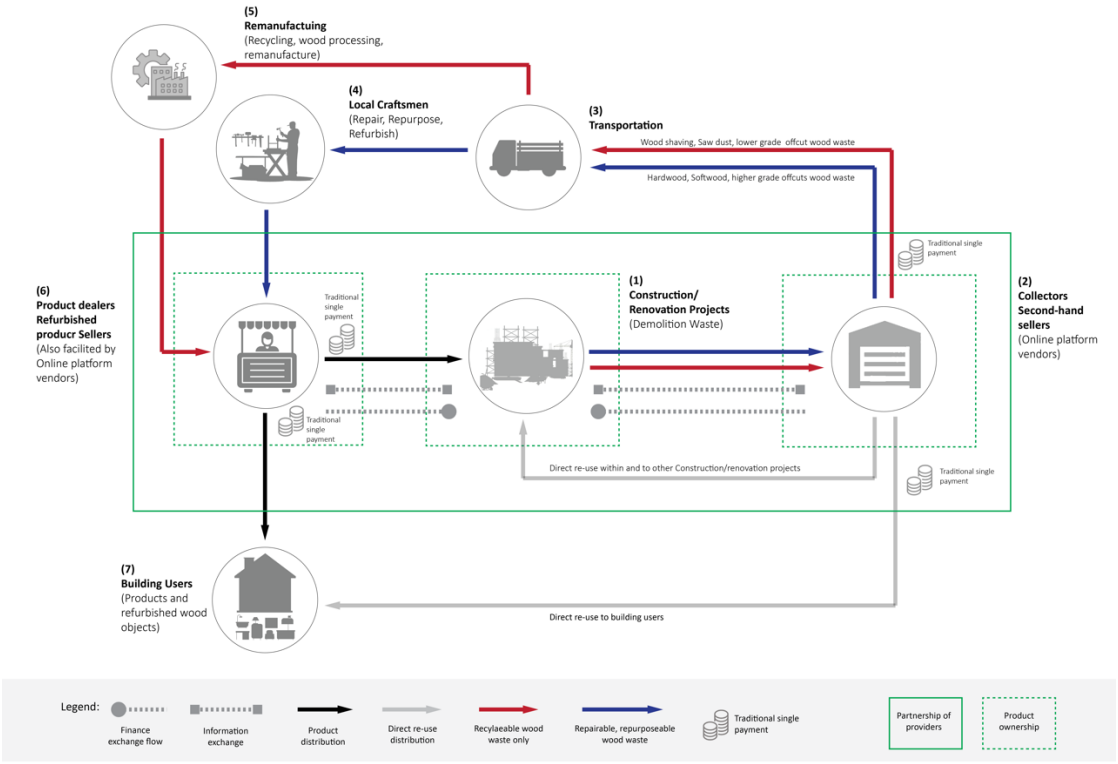

Figure 6. Proposed Circularity Model for Construction/Demolition Wood Waste in the African contexts of Kenya and Nigeria. Source: Authors

The key features of the model in Figure 6 would be (A) original products not designed for re-manufacturing or facilitating features, (B) Procurement mechanism of buy-back mechanism from the collectors or second-hand sellers, (C) the product collection in these African countries is mainly done by collectors, but manufacturers could be involved with more awareness and profitability, (D) The re-manufacturers are independent of the original product manufacturers. (E) The local re-manufacturers may not re-design the new products with the intention of re-manufacturing as the new ownership is completely transferred to the new customer. (F) the distribution of the products will involve the local dealers of refurbished wood products and possible partner of online vendors. (G) the re-manufactured product ownership will be completely transferred to the customer. (H) The single payment system is the predominant revenue system in these two countries. (I) The re-manufactured products (upcycled or downcycled) can be reused in the same market destination as the original product in construction projects and to other wood market destinations of furniture products. These key features could be altered based on the company or organization attributes that would adopt the model organization, by referring to Re-NeTA's key features of the circularity model in table 5 below.

Table 5. Proposed Circularity Model for Construction/Demolition Wood Waste in the African Contexts of Kenya and Nigeria (MD1) Key Features

Key Features		**Possible configurations**		**CS 3**
A	Original product design	A1	Product designed for re-manufacturing	
		A2	**Products not designed for re-manufacturing**	
		A3	Product not designed for re-manufacturing but with facilitating features	
B	Product procurement	B1	Surcharge-based mechanism	
		B2	**Buy-back mechanism**	
		B3	Direct order mechanism	
		B4	Service contact mechanism	
		B5	Leasing mechanism	
C	Product collection	C1	Enabled by collectors' activity	
		C2	Performed autonomously by the re-manufacturer	
		C3	**Hybrid solutions**	
D	Re-manufacturing actors	D1	Original Equipment Re-manufacturer	
		D2	Contracted Re-manufacturer	
		D3	**Independent Re-manufacturer**	
E	Re-manufactured product design	E1	Product re-designed for re-manufacturer	
		E2	**Product not re-designed for re-manufacturing but with facilitating facilities**	
		E3	Product not re-designed for re-manufacturing	
F	Product-service distribution	**F1**	**With a partner intermediation**	
		F2	**With a dealer intermediation**	
		F3	Performed autonomously by re-manufacturers	
G	Product Ownership	**G1**	**Ownership is transferred to the customer**	
		G2	Ownership is retained by the provider	
		G3	Ownership is transferred to the customer with provider extended responsibilities.	
H	Revenue system	**H1**	**Traditional single payment**	
		H2	Deposit-based single payment (with surcharge)	
		H3	Performance payment (Pay-per-use, Pay-per-period)	
I	Market destination and segment	**I1**	**Same market destination and segment of the original product**	
		I2	Same market destination as the original product but a different market segment	
		I3	**Different market destination from the original product**	

5. DISCUSSION/RESULTS

The proposed circularity model on construction wood waste makes effort towards answering some listed research gaps from previous literatures. The model provides attributes or strategies of managing construction wood waste through an interactive material supply chain from construction or demolition wood wastes through local waste collectors or online sharing platforms through second-hand material sellers, through local craftsmen (re-purposing) or wood recyclers (re-manufacturing) to refurbished material sellers or home product furniture or back to construction project again. The approach of the proposed model in the context of Kenya and Nigeria as guided by stakeholders' input is a further advancement of the literature on circular economy in Africa with specific business implementation model as suggested by Desmond & Asamba, (2019). More also the study results by Bello et al., (2024) reveals the lack of adequate business model as one the key barriers identified from stakeholders' response affecting the implementation of circular economy in the construction sector of developing countries. The model as illustrated in figure 6 provides two outlets first for higher grade wood wastes in blue lines (Hard wood and soft wood) and secondly lower grade wood wastes in red lines (wood shaving). Higher grade wood waste can be repurposed by local craftsmen, although the craftsmen would

need a level of training or knowledge on working with construction wood wastes, while the lower grade wood wastes would require wood waste recycling factories which are not prevalent in either Kenya or Nigeria. These two outlets of flow on the proposed model is similar to the reuse and recycle outlet for construction/demolition wood waste circular economy framework by Jahan et al., (2022), in alignment with the contexts of Kenya and Nigeria to achieve a circular economy model that is comprehendible to the local audience (Hartley & Kirchherr, 2023) with the use of simplified illustrations, inclusion of local business attributes and the inclusion of all relevant key stakeholders, both formal and informal practitioners. The approach can be feasible as given by the stakeholders' responses, thereby preventing further landfill disposals, creating stakeholders' interaction, creating possible job opportunities and economic benefits to the involved stakeholders. Justifying the range of benefit coverage for a circular economy model by Jayakodi et al., (2024) to include economic, environmental and social value for stakeholders, creating a sustainable business environment. However, this is only a theoretical aspect and will need a practical implementation with the necessary communication tools in place, to measure its success rate.

5.1 Stakeholders' Response to Circularity Models.

The response from the poll of structured survey questionnaire reveals positive responses on the feasibility of the Circularity model. The poll of survey questionnaire illustrated in table 6, was responded by 15 stakeholders from Kenya and 13 from Nigeria during online webinars and meeting of Kenyan Green Building Society (KGBS) and Green Building Council Nigeria (GBCN). In the survey results graph of figure 7, respondents from Kenya (a) 69.2 percent agreed that the proposed circularity model is feasible in Kenya, while from Nigeria 38.5 percent agreed the proposed model is feasible and another 38.5 agreed it fairly feasible. Furthermore, (b) 53.8 percent of the respondents from Kenya strongly agreed and 61.5 percent from Nigeria agreed that Circular Economy practice can improve construction wood waste management, (c) the respondents from Kenya highlighted possible benefits of wood waste output through circularity with the prevention of environmental deterioration coming in first place, followed by creation of more business opportunities and provision of secondary material alternatives. The same was in Nigeria but, the respondents included the option of more affordable reused wood products from circularity. The above results are like the economic, environmental and social benefits of adopting circular economy strategies in the construction sector, highlighted by John et al., (2023). (d) The respondents from both countries also highlighted major challenges that could affect the achievement of the circularity model for construction wood waste which include lack of government supporting policies, lack of stakeholders' interest, lack of Stakeholders' awareness, and lack of supporting information tools and frameworks, these results from stakeholders response is similar to the barriers highlighted by Charef et al., (2021) and Bello et al., (2024). This circularity model for construction wood waste, adoptable by interested stakeholders would provide a supporting framework to enable stakeholders to define their wood waste material flow. (e) This model can also be re-interpreted by stakeholders to include other measures they highlighted in table 7, that can improve the circularity model which includes early-stage designs decisions, involvement of government regulations, introduction of building information modelling (BIM), and introduction of independent storage warehouses. Similarly, the study by Charef & Lu, (2021) highlighted the use of building information modelling, design modularization, design with reclaimed components, and set-up strategies for storing recovered materials as factors for facilitating circular economy adoption in the construction sector. Also, the study by (Bello et al., 2023) highlighted the importance of government regulations, penalties and incentives as drivers for promoting circular economy strategies in the construction sector especially in the context of a developing country.

Table 6. Respondents' Information

	Kenya		Nigeria	
	male	female	male	female
Architects	*****		***	**
Builders	*		**	
Civil/Structural Engineer			**	
Electrical/Electronic Engineer	**			
Construction Manager	***	**	*	
Researcher			*	
Developer			*	
Quantity surveyor				*
Landscape architect		*		
Project manager	*			

Table 7. Stakeholders' Response to Other Measures That Can Improve the Proposed Circularity Mode for Construction Wood Waste

	Kenya	Nigeria
Early design stage decisions	1st place	1st place
More involvement of government regulations (officials)	3rd place	2nd place
Introduction of BIM (Building Information Modelling) in the process	2nd place	3rd place
Introduction of independent warehouse storage facilities	4th place	4th place

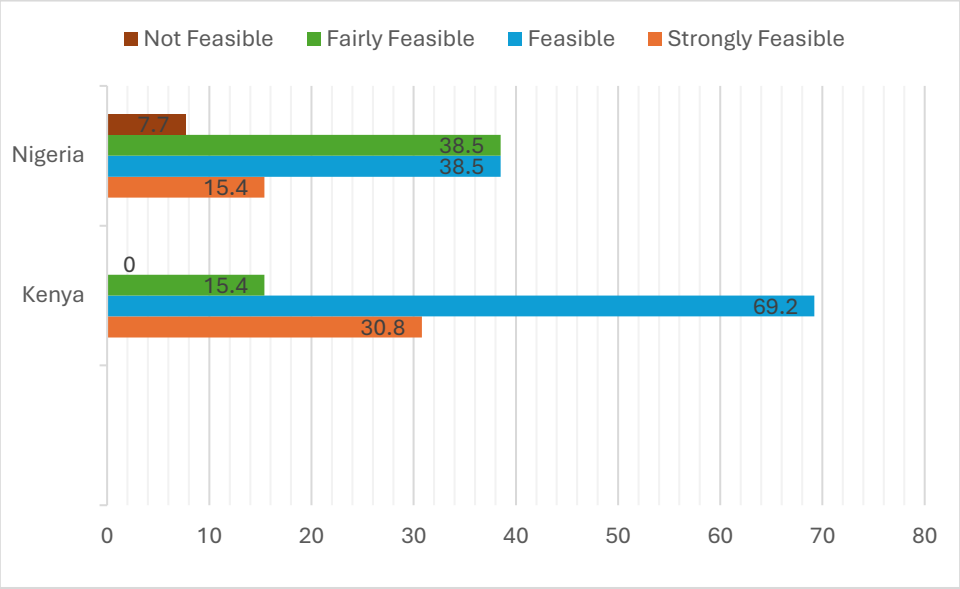

Figure 7. Percentage of Stakeholders' Response to the Feasibility of the Proposed Circularity Model

6. CONCLUSION/ RECOMMENDATIONS

The stakeholder's responses from both Kenya and Nigeria reveal a positive feasibility for the proposed circularity model. Considering the presence of small and medium-scale construction companies, local craftsmen, and local waste collectors in these two countries which is a similar case to most developing countries in Africa, the proposed circularity model can provide a linkage with established construction companies through the sharing of information, this can also be enabled with the introduction of online material sharing platforms. From the survey, stakeholders agreed the model would enable a better management of construction wood waste. Creating more opportunities for collectors, second-hand

material sellers, and local craftsmen, connecting their businesses with small-medium enterprises (SMEs) construction companies and large established construction companies.

However, the achievement of circular economy practice for construction wood waste would still require introduction of government policies/regulation, establishment of wood waste recycling factories, stakeholder network and the adaptation of circularity models. To boost these circularity activities, it would require the support of Government policies and regulations to facilitate easy transition from a linear to a circular economy, it would require technological advancement through the establishment of wood waste recycling factories to enable efficient management of lower grade wood wastes that can only be recycled, before been used to manufacture other wood products and the network of relative stakeholders for easy flow of the supply chain, an example of such network is the Rilegno Consortium in Italy established by government decree to promote wood waste reuse/recycling by bringing together wood waste recyclers, remanufacturers and collectors. More measures may need to be included when a company chooses to adopt this circularity model, which includes early design stage decisions, introduction of building information modelling, and the creation of independent storage facilities. The flexibility of the proposed model refers to stakeholders altering the given key features in accordance with the features provided by ReNeTA approach to suit their business narrative. It would also be important to explore a model of circularity for other construction waste like concrete and reinforcement steel. Further aspects of the construction wood waste circularity model would involve determining the effectiveness of the model through a continuous practical practice with relative stakeholders. Further areas of research on a construction wood waste circularity model could be on specific wood types/wood products by a wood product manufacturer and the model assessment from other developing countries in Africa and beyond to expand the literature base of construction sector circular economy strategies in developing countries.

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AUTHOR CONTRIBUTIONS

Christian Jonathan: Is a PhD candidate at Politecnico di Milano University, initiator of this scientific work and preparation of the paper including conceptualization, data curation, methodology, investigation, validation, writing-original draft, visualization, writing-review and editing.
Judith Onyoni: Is a tutorial fellow at Technical University of Kenya and was involved in the preparation of this paper including methodology, investigation, validation, writing-original draft, writing-review and editing.

DECLARATIONS

Data availability. The survey data analysed during the research are available from the corresponding author on reasonable request.
Ethics approval and consent to participate. All the participants of the survey confirmed they agreed to participate in the survey and their consent to publish the results.
Competing interests. The authors declare no competing interests.

APPENDIX

For full-size figures click here or copy the following to your URL bar:
http://circulareconomyjournal.org/wp-content/uploads/2025/02/Appendix_Jonathan_and_Onyoni_A-Feasible-Circularity-Model-for-Construction-Wood-Wastes-in-Developing-Countries-The-Case-of-Kenya-and-Nigeria.pdf

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