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Developing a Model for Recycling Construction Waste towards Effective Project Costs Control in Kebbi State.

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ABSTRACT

Construction, alteration and demolition waste (CAD) is a major source of urban solid waste, frequently accounting from10–30% of the total waste disposed of at landfills and Open Dumping in many cities around the world. There is a recognized need to manage the construction waste in order to maintain a sustainable and healthy environment. The successful implementation of construction waste management depends on a number of factors. One critical factor is the need to accurately estimate waste generated from construction projects. In this regard, this research proposal was propose a quantitative construction waste and its recycled value model for effective cost control in building construction projects, which can enhance the accuracy in using recycled construction waste at the project level. In the development of this model, a theoretical analysis of the construction process and the construction waste generation process has been conducted. Specifically, this model will integrate the mass balance principle (MBP), material quantity take-off (MQT), conversion ratios between different waste measurement units, and the wastage levels of various materials used in different work packages. The proposed model is able to predict the quantities of various kinds of construction waste and testing the strength of the recycle materials with the new products from a building project before starting of the work, to track the origin of construction waste from which work package a particular kind of waste is generated and how much and to help contractors investigate the potential improvements for waste management. It was recommended that an account of all construction waste generated in the major cities of all the four Emirates in the state will be carried out in order to assess the feasibility of large-scale recycling of construction and demolition waste.

***Key words**: construction waste, recycling, and cost control*

Introduction

Kebbi State is one of the 36 States in Nigeria that is currently experiencing economic growth. Along with this growth, the state is also witnessing rapid urbanization, with the estimated percentage of its total population residing in urban areas rising from 21.5% in 1991, when the state was created, to 24.3% by 2021, and it is expected to continue to increase (Kebbi Urban Development Agency, 2001). The swift urban development in Kebbi has created a higher demand for housing and infrastructure, which, in turn, results in substantial amounts of construction waste.

Construction waste refers to the refuse produced from a variety of activities, including site clearing and the construction of new buildings or infrastructure (Fatta et al., 2003). This waste can originate from construction, alteration, and demolition (CAD) practices, encompassing the materials generated during the erection of new structures, renovations, and the dismantling of existing ones. Typically, this waste is sent to landfills; however, increasing awareness of the possibility to redirect waste materials from landfills has made CAD waste a focus for recycling efforts. Numerous studies have sought to assess the volume of construction, alteration, and demolition waste across different regions. In the United States, approximately one-third of landfill volume is comprised of CAD waste (Chun-Li et al., 1994; Kibert, 2000). Data from various European nations suggests that the quantity of CAD waste differs from one country to another, depending on its definition. In 1996, the estimated CAD waste per capita for Austria, Denmark, Germany, and the Netherlands was approximately 300, over 500, around 2600, and about 900 kg, respectively (Brodersen et al., 2002). Additionally, it has been noted that CAD waste occupied roughly 65% of landfill space in Hong Kong at its highest point in 1994–1995 (Stokoe et al., 1999). Research conducted in the United States by the Environmental Protection Agency (USEPA) has focused on the reduction, management, and possible uses of construction waste. Estimates suggest that around 136 million tons of construction-related waste were generated in 1996 (US Environmental Protection Agency, 1998). According to Rogoff and Williams (1994), construction waste makes up roughly 29% of the solid waste stream in the United States. In Canada, construction waste occupies 35% of landfill space, while more than 50% of the waste in landfills in the United Kingdom (UK) could be attributed to construction waste (Ferguson et al., 1995). Moreover, investigations into Australian landfills have indicated that construction activities account for approximately 20-30% of all waste deposited (Craven et al., 1994).

In most of these countries, increasing attention is being given to diverting as much construction waste as possible from landfills through waste reduction, recovery, reuse, and recycling. Therefore, the research project aims to present a model for the estimation of the amount of waste to be produced from a construction project at the early stage for effective cost control. In a context of increasing international concern about sustainability, numerous instruments have been recognized to reduce construction waste and to improve the recycling rate of construction waste, i.e., site waste management plan (Tam, 2008) and landfill charge scheme (Hao et al., 2008). The effective application of these instruments depends heavily on the accurate quantification of construction waste at the project level, which is a practical level for both the government and the construction industry to take effective measures to control construction waste.

From the government's standpoint, authorities need a precise assessment of construction waste to formulate suitable policies, guidelines, strategies, and practices for sustainable waste management tailored to the local context. This is crucial for developing effective waste treatment facilities, determining appropriate waste charges, and creating suitable incentives for construction firms to adopt proactive measures, such as utilizing site waste management applications and implementing green building technologies to reduce construction waste. From the perspective of construction firms, a waste estimation system implemented at the project initiation stage enables companies to accurately gauge the quantities of different types of waste produced in each project. This allows for active planning in waste prevention, reduction, and utilization, both within individual projects, across multiple projects by a single firm, or throughout the entire construction sector. In numerous nations, the significance of reusing and recycling construction waste has been recognized; in Nigeria, the rising unregulated disposal of construction debris and the shortage of landfill capacity are emerging as critical problems. Consequently, the management of construction waste is an essential priority, particularly in metropolitan areas, state capitals, and Abuja, where population density is higher and the rate of construction is greater compared to other regions, as evidenced by the annual number of new construction permits (Abuja FCDA, 2020; Kebbi State Urban Development Agency (KUDA) 2007). Nonetheless, there is limited knowledge regarding the amount of construction waste produced in Kebbi State, which hampers effective cost control; developing an estimated model will assist construction management in assessing the expected waste generation before the project begins. Furthermore, the text emphasizes key issues surrounding the potential and advantages of recycling construction waste in Nigeria, and it also addresses the present state of construction waste management in Kebbi State.

This paper aims to develop a model for Recycling Construction Waste towards Effective Project Costs Control in Kebbi State.

The strength of this study primarily revolves around two key aspects: first, it examines critical activities related to waste management, cost control, and the recycling of construction waste. Second, it employs the MBP and MQT methodologies, which not only encompass a range of activities but also anticipate their dynamic interactions. The paper is structured into four sections. Initially, it addresses construction waste management, recycling, and cost control. This is succeeded by the development of a model aimed at analyzing the benefits of recycling waste for cost management. Following this, the application of the proposed model is discussed, along with an analysis of the results and discussions that are integral to this research endeavor. Finally, the paper concludes with a recap of the main findings.

Review of the related literature

Current practice and problems of construction waste management in Nigeria

Construction waste management practices and challenges in Nigeria indicate that this type of waste is grouped under municipal solid waste (MSW). It is typically gathered manually and placed through a temporarily built refuse chute to the ground. Subsequently, it is removed from the construction site by either the primary contractor or a subcontractor. A study of 15 construction sites in Kebbi state showed that approximately 87% of construction companies tend to handle the disposal of these wastes internally, while the remaining 13% outsource the disposal to subcontractors or other individuals. Furthermore, existing data reveal that most construction waste is discarded either in uncontrolled locations or other unsuitable sites (Ashford et al., 2000; Padungsirikul, 2003). Therefore, it is crucial to develop laws and policies that encourage these companies to monitor and report the amount of construction waste they produce, along with the method(s) of treatment and disposal. Generally, materials like wood are reused by contractors on-site as frequently as possible to eliminate the costs associated with collection and disposal, as well as the added expense of new materials. Scrap dealers commonly retrieve scrap metals (mainly off-cuts of metal sheets and bars) and other recoverable materials generated, reselling them to second-hand buyers or, in the case of metals, to metal smelting companies. While the collection and sale of these materials by recyclers represent a beneficial approach to reuse and recycling, it lacks systematic efficiency (Esin and Cosgun, 2005).

A 2004 survey regarding solid waste disposal systems in the state indicated that 77.6% of the 425 disposal sites were open dumps (Table 1), with the remainder being landfills (Chiemchaisri et al., 2006). It was estimated that in 2010, between 16–34% of the collected MSW in Nigeria contained recyclable materials; however, only 7% (equivalent to 2,360 tons/day) was actually recycled (Padungsirikul, 2003). This figure is significantly low compared to the recycling rates for construction and demolition (CAD) waste in other nations. In Denmark, the recycling rate exceeds 80%. Countries like Germany and The Netherlands, Finland, Ireland, and Italy recycle between 30–50%, while Luxembourg has a recycling percentage of 10% (Brodersen et al., 2002). Even building rubble (comprising concrete, brick, tile, and asphalt), which is typically disposed of in open dumps in Nigeria, is recyclable. In Australia, building rubble is the most recycled material. Data from the Australian Government Productivity Commission (2006) revealed that in 2002–2003, around 50% of all recycled waste in Australia comprised CAD waste. Numerous technologies for recycling construction waste are available (Tam and Tam, 2006a).

Table 1: Solid waste disposal sites in Kebbi State

Kebbi senatorial zones	Land fill	Open Dumping	Land fill	Open Dumping	Land fill	Open Dumping
North	17	56	1.3	2.6	477	1214
Central	30	100	2.2	2.2	1162	2263
South	22	70 1	1.4	2.0	854	950
Total						

Construction waste generation in Kebbi State

Construction activities such as site clearing and the erection of new buildings or infrastructure contribute significantly to construction waste (Oyeshola et al., 2009; Fatta et al., 2003). In Kebbi State, construction waste is typically seen as a crucial component of municipal solid waste (MSW). The management of MSW has been identified as a major challenge, with its volume and characteristics having been recorded. The total generation of MSW in Kebbi State rose from 5.2 million tons in 2010 to 8.3 million tons in 2012 due to ongoing construction projects. Furthermore, the average per capita generation rate increased from 0.53 kg/cap/day in 2010 to 0.62 kg/cap/day in 2011. This trend indicates a growing quantity of MSW generation in Kebbi, along with an increasing per capita rate, highlighting the necessity for a sustainable strategy for disposal and management (Ka'oje thesis 2013; Chiemchaisri et al., 2006). In 2003, the daily total of MSW generated in Kebbi was around 40,165 tons (Table 2). Data from the Pollution Control Department of Nigeria (2011) reveals that approximately 84% of total solid waste in Nigeria is categorized as MSW, while 12% comprises industrial waste, including 8% that is classified as hazardous. The characteristics of MSW indicate that a significant majority is composed of putrescible materials, paper, and plastics.

While materials such as wood, glass, and metals, which are part of construction and demolition waste, may also serve as building materials, it remains uncertain whether these waste materials originated from construction activities, as they might also stem from non-construction-related activities. It is noteworthy that despite the lack of in-depth studies on MSW in Kebbi State (Kebbi State Urban Development Agency 2007; World Bank Group, 1999), there is limited information regarding the management and recycling of construction waste, as no existing system monitors the quantity of collected construction waste. Consequently, there is a pressing need for a waste management system that monitors waste from its source and provides details about its composition and other relevant aspects (e.g., volume).

The primary components of construction waste in Kebbi State, as observed through site visits and corroborated by earlier research (Oyeshola et al., 2009; Chanchorn, 2002), include steel reinforcement, wood, concrete, cement, bricks/blocks, tiles, and roofing sheets. Waste produced at construction sites might result from inadequate consideration of product sizes, contractors' lack of interest, or insufficient knowledge of construction during design phases. Additional factors, such as poor material handling that may cause breakage (e.g., of bricks), also play a significant role. Approximately 1% to 10% by weight of the construction materials purchased, varying by material type, ends up as waste on site. In general, between 50% to 80% of construction waste is reusable or recyclable (Oyeshola et al., 2009; Ferguson et al., 1995).

Estimation of construction waste generation in Kebbi State

Estimating the generation of construction waste in Kebbi State is a complex endeavor. This complexity arises primarily from the absence of requirements for construction firms to document and disclose the qualitative and quantitative aspects of the waste they produce. As a result, to estimate construction waste generation, data regarding the types of building activities, along with the number and area (m2) of construction permits (refer to Table 1), were sourced from the Kebbi Urban Development Agency KUDA database (2020). To assess the volume of construction waste produced, the following assumptions were employed: (a) the waste generated by new residential construction is 21.38 kg/m2, and (b) new non-residential construction results in 18.99 kg/m2 (HQ Air Force Centre for Environmental Excellence, 2006). The calculation of construction waste was carried out using the methodology specified by the HQ Air Force Centre for Environmental Excellence (2006). This study focused on estimating the waste arising from construction activities that occurred between 2010 and 2013. The waste generated from the construction and maintenance of infrastructures such as bridges and highways was not included due to insufficient data on these activities. Additionally, any form of demolition was also excluded for the same reason.

The problem of construction waste management in Nigeria

The challenges faced are comparable to those encountered by other countries in Africa in several ways, including; (1) inadequate financial resources allocated for municipal solid waste (MSW) management and inefficient collection of service charges; (2) a lack of proactive planning for the establishment of shared disposal facilities among nearby communities; (3) the absence of clear regulations and guidelines for managing construction waste in a hierarchical manner that includes source separation, collection, transportation, disposal, and monitoring; (4) a shortage of qualified personnel to implement effective waste collection and disposal practices; (5) the lack of waste recycling initiatives in the majority of communities; (6) existing legislation is insufficient to support effective construction waste management; (7) limited public cooperation and involvement; and (8) inadequate legal enforcement from the government, among other issues (Shen and Tam, 2002). It is important to note that while some of these issues are common in various regions, there can be significant differences regarding potential management strategies (e.g., distances, skilled personnel availability, technologies, etc.). Still, having sufficient information on certain factors, such as the volume and nature of construction waste, is vital for assessing and promoting the effective implementation of possible strategies and existing waste management plans. Various environmental management regulations prohibit illegal dumping of waste and assign full responsibility to local authorities for creating ordinances and overseeing solid waste management systems, including collection fees in specific areas like Central Market Birnin Kebbi and Eid ground. One such regulation is the Environmental Protection Act (Ministry of Environment and Natural Resources Kebbi State, 2007). The data revealed that construction activities in Kebbi State produced an average of 1.1 million tons of construction waste annually (see Table 3). Based on Kebbi's population data from 2012 to 2015 (KUDA, 2007) and considering the time-series data of construction activities during the same period (Ministry of Works and Housing Birnin Kebbi, 2012), it was noted that the volume of construction waste generated in Kebbi has increased over time. In 2010, approximately 12 kg of construction waste was produced per person; this figure rose to around 18 kg in 2011 and 22 kg in 2012, followed by a slight decline to about 20 kg per capita in 2013 (Table 3). This suggests an average rate of construction waste generation of around 18 kg per capita per year in Kebbi during this timeframe. The minor decrease in waste generated in 2013 can be attributed to a reduction in new construction activities compared to 2012. The calculated amount of construction waste generated per resident in Kebbi cannot be directly compared to figures from other states, which report construction and demolition waste generation per person ranging from approximately 200 kg per capita for Kaduna. The material generated by the Portland cement crushing and demolition processes is utilized to create recycled concrete aggregates (RCAs). When producing nano cement and concrete at central recycling facilities, it's crucial to maintain consistency according to a specific mix of materials sourced from various origins. The original materials must include concrete that meets specific standards and undergoes rigorous quality control at the source. Recycled concrete aggregates (RCAs) present significant potential as a substitute for natural coarse aggregates (NCAs) due to their advantageous cost-benefit ratio and excellent disposal characteristics as illustrated in Fig. 2. The main challenges associated with RCAs include their unpredictability and the general awareness among contractors regarding their benefits (zaid et al., 2024).

Benefits of recycling construction waste

Recycling, a method for minimizing waste, provides three key advantages: (i) lessening the need for new resources; (ii) decreasing the energy costs associated with transportation and production; and (iii) minimizing the land area needed for landfills (Tam and Tam, 2006b). Additionally, the societal effects of solid waste management systems are evident in the employment levels, health, and overall quality of life for residents in the area. Salvaging, recycling, and reusing construction waste can lead to cost savings and generate jobs linked to the salvaging and recycling process. Moreover, the health and quality of life for community members enhance when pollution is minimized by lowering emissions related to manufacturing and transport through salvaging and recycling efforts. There are various estimates regarding the job creation potential of recycling. Despite these differing figures, it is evident that among all waste management methods, land filling and incineration provide the least number of jobs. For instance, Macdonald (1998) reported, citing the World watch Institute, that for every 150,000 tons of waste processed, recycling generates nine jobs, incineration leads to two jobs, and land filling results in just one job. Conversely, according to the US Environmental Protection Agency (2002), incinerating 10,000 tons of waste results in one job, land filling that amount creates six jobs, and recycling it generates 36 jobs. Applying these figures to Thailand's context, it was estimated that recycling construction waste could create between 70 and 500 jobs during the period of 2010–2012 based on the projected annual generation of construction waste. To highlight the economic benefits of recycling construction debris, the energy savings across the country were calculated when materials from construction waste, such as ferrous metals, wood waste, and concrete, were recycled. Concrete is typically crushed and reused instead of new aggregate in a wide range of construction uses, including as road base, fill, and a component in both concrete and asphalt pavement (Cochran and Villamizar, 2007). This practice reduces the energy required for producing concrete with virgin aggregate. Consequently, the advantage of recycling concrete stems from the energy saved by eliminating the need to mine and process the aggregate it substitutes (US Environmental Protection Agency, 2003a). To assess the benefits of recycling concrete in place of virgin aggregate, certain assumptions based on information from the US Environmental Protection Agency (2003a) were adopted.

(a) Process energy for the production of 1 ton of virgin aggregate = 51.3 MJ/ton

(b) Process energy for the production of 1 ton of recycled aggregate = 37.1 MJ/ton

Cost control

Cost control involves implementing strategies to ensure that the total sum for a construction contract or project is not surpassed; in simpler terms, it can be described as the practice of managing expenses within the timeframe outlined in the contract. The primary goal of cost control is to maximize the efficient use of resources. Given the current trend of escalating costs, many project sponsors are demanding that construction projects are planned and executed to provide the best value for expenditure. Consequently, quantity surveyors are increasingly consulted during the design phase to advice architects on the likely cost effects of their design choices, as buildings become more intricate and material waste increases during construction. Therefore, it is essential to enhance and fine-tune cost control methods to address the rising costs, capital restrictions, high-interest rates, and government policies. These factors have led clients to insist that professional advisors integrate cost considerations into their designs and deliver balanced costs across all components of the building, while also providing accurate predictions of the total expenses. (Lockey, 2002).

Cost Control Techniques

There are various methods used in controlling cost by various organizations. The techniques are evolved by the accounting department with cost and management section at the core of implementation. Those techniques are includes the following; budgetary control, standard costing and material control.

Budgetary Control

In any organization, a budget can be described as a formal representation of the anticipated income and expenses over a specific future period. Lucey (1996) characterizes a budget as the financial representation of a company's plan for a future timeframe. The Institute of Cost and Management Accountants defines a budget as a financial and/or quantitative statement that is prepared in advance for a designated time period, outlining the planned actions to be taken during that time to achieve a specific objective. Budgetary control focuses on the effective utilization of resources to meet one or more predetermined objectives outlined in a plan (Sikka, 2003).

Cost Control Application

Regular information about operational activities is essential for businesses to plan for the future, manage current activities, and assess the past performance of managers, employees, and related business segments (Cooper et al., 2000). To achieve this, management guides the activities of employees in accordance with set goals and objectives. Cooper et al. (2000) also emphasize that behavioral management focuses on the attitudes and actions of employees, which ultimately influence success. Behavioral management includes specific issues and assumptions that do not apply to accounting control functions. Conversely, performance evaluation assesses employee outcomes by comparing actual business results to pre-established success standards. Through this process, management identifies strengths to enhance and weaknesses to address.

Benefits of Cost Control

The benefit of Cost control is to enhance the efficiency of management and if necessary, should result in action being taken to reduce the cost for profit purposes and to prevent fraud and efficiency (Dury, 1985). Some of these benefits are as follows: 1) A simple control can be expressed over all operation from the purchase of goods to account for sales. 2) An efficient cost control with reveal possible sources of economy and result in a rational utilization of material and labor. 3) Cost control makes policy decisions by management very easy. 4) It ensures adequate production and prevents overstocking of material.

Cost Reduction

Cost control focuses on aligning actual expenses with established targets, while cost reduction seeks to lower those targets themselves. In simpler terms, cost reduction involves exploring opportunities to decrease expenses related to materials, labor, overheads, and more. The Institute of Cost and Management Accountants in London defines cost reduction as successfully achieving a lasting and genuine decrease in the unit costs of produced goods without compromising their intended usability. Therefore, the concept of cost reduction refers to authentic savings in production, administration, marketing, and distribution costs, which result from the removal of unnecessary and wasteful components from the product design and the associated techniques and practices. The need for cost reduction emerges when there is a requirement to enhance profit margins without increasing sales revenue, meaning that costs must be lowered for the same sales volume.

Importance of Cost Control in Business

According to Lockey (2002), the significance of cost control in business operations has been analyzed. The control function is essential for aiding business management in various ways. It assists management in reaching set objectives. The control process also evaluates the efficiency of different functions. Limitations in several areas are reported to prompt corrective actions and provide a foundation for future initiatives. Continuous information flow regarding projects keeps long-term planning aligned. Furthermore, it enables management to avoid repeating past errors. Control facilitates decision-making regarding future actions whenever there is a discrepancy between standard and actual performance. Coordination through unified action is attained via control. Managers strive to effectively coordinate their staff's efforts to ensure departmental goals are achieved. Enhancing organizational competence is made possible through the control system. Clearly, a manager’s performance is regularly assessed, leading to improvements over their past work. A manager's performance is associated with both pros and cons. Workers will consistently face pressure to enhance their responsibilities. A crucial tool for control is performance measurement, which ensures that each individual optimally contributes.

Break- down between Cost Reduction and Cost Control

Controlling costs involves managing expenses to stay within a specific limit. The focus is on adhering strictly to the established budget to prevent costs from exceeding the defined standards. In contrast, cost reduction is an active and intentional effort aimed at lowering expenses regardless of their current levels. Each component of cost is examined, every process is scrutinized, and various methods are assessed to identify ways to reduce costs. There is a distinction between cost reduction and cost control regarding their approaches. Costs are analyzed for each cost center individually, with budgets prepared in advance to prevent the influence of favorable variances on unfavorable ones. This approach enhances the effectiveness of cost control. Conversely, cost reduction is deemed successful when expenses are lowered overall across the entire organization. When reductions are compiled at the corporate level, they can lead to significant savings. Furthermore, cost reduction is not a one-time event; it requires a mindset, approach, and philosophy. The essence of cost minimization is deeply rooted in a culture of cost awareness among all individuals involved. Therefore, the primary way to foster cost consciousness is by reducing costs at every level and emphasizing the roles and responsibilities of each employee within the organization.

Proposed Construction Waste Model

The mass balance principle (MBP) and material quantity take-off (MQT) concept involves a systematic hierarchical division of a project into increasingly smaller work packages, down to terminal work packages, where various construction engineering and management tasks can be effectively implemented. This classification system for construction information breaks down project components into a manageable level and serves as an integration mechanism that provides a unified viewpoint for relevant construction business activities (Jung and Woo, 2004). These concepts are seen as a robust project structuring tool, extensively utilized to sequence construction operations, perform material quantity take-offs, estimate construction time and costs, link costs with schedules, assess construction progress, enhance safety and quality, and improve interface management (Chen, 2008; Chua and Godinot, 2006; Kim et al., 2008). The concepts are based on the Uniformat II classification standard, which categorizes common building elements according to their functions, irrespective of their design specifications, materials employed, or construction methods/technologies utilized (Charette and Marshall, 1999). In the

Uniformat II framework, a building construction project is divided into four hierarchical levels: major element groups at Level 1, which are referred to as systems; grouping elements at Level 2, termed components; individual elements at Level 3, also known as elements; and sub-elements at Level 4 (Zhang, 2006). Level 1 encompasses the broadest identification of element groupings, such as substructure, shell, interiors, services, equipment and furnishings, special construction, and site work. At Level 2, these systems are further categorized into components; for example, the substructure is divided into two main components: foundation and basement construction. Level 3 further divides these components into elements; for instance, basement construction is separated into two elements: basement excavation and basement wall. Level 4 represents sub-elements created by breaking down Level 3 elements; for example, the basement wall consists of various sub-elements like basement wall construction, moisture protection, basement wall insulation, and interior skin. The mass balance principle (MBP) and material quantity take-off (MQT) are utilized for building construction projects following the Uniformat II classification.

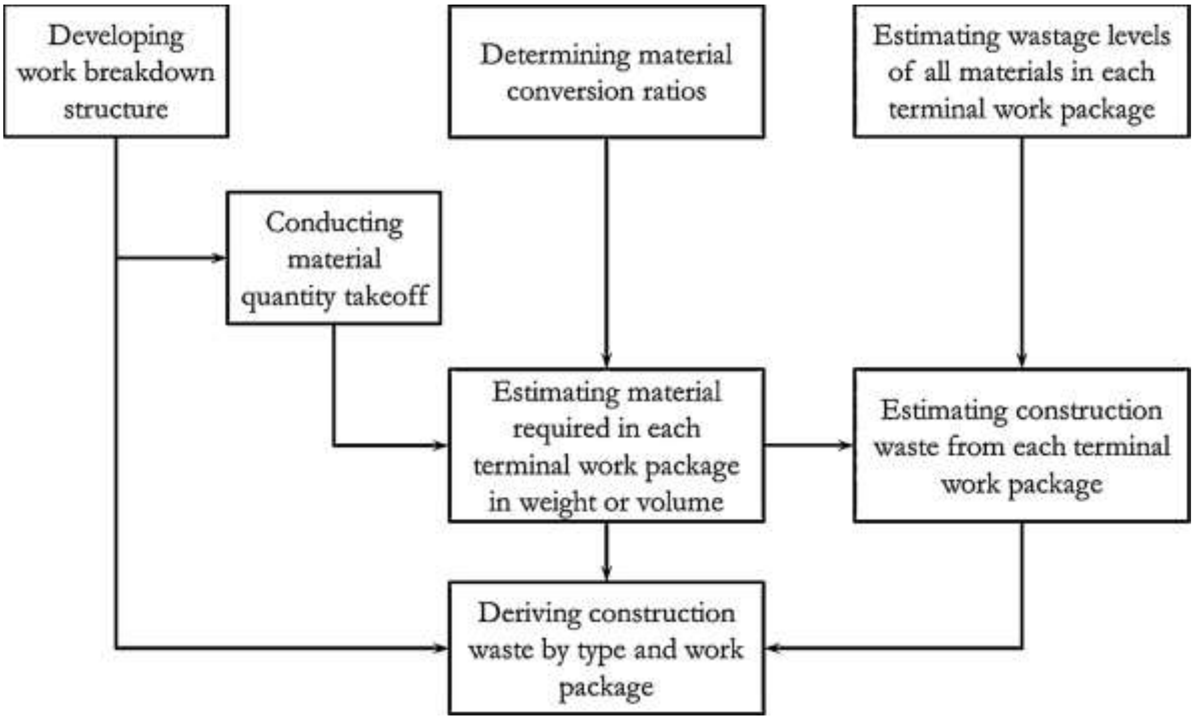

Fig. 1. Overall methodology in developing the proposed waste estimation model.

Methodology

Akintoye (2010) asserts that prior to undertaking a comprehensive research project, it is essential to have a well-structured plan of study. This ensures that the study yields the necessary data while minimizing costs. Asika (2005) defines research design as the framework of an investigation that aims to identify variables and their interrelatedness. Thus, it outlines how the investigation is organized to help the researcher gather pertinent information to address the identified research issue. The research design applied in this study is laboratory research.

The overall methodology for developing the construction waste estimation model involves a theoretical examination of the construction process as well as the generation of construction waste. In particular, Work Breakdown Structure (WBS), Mass Balance Principle (MBP), and Material Quantity Take-off (MQT) will be utilized to illustrate various construction processes. In a WBS, the lowest practical level of work packages is designated as terminal work packages for this project. Utilizing the Mass Balance Principle (MBP) and Material Quantity Take-off (MQT), the material quantity take-off assists in determining the required amounts of materials for a particular building project. The Mass Balance Principle and Material Flow Analysis (MFA) are applied to analyze the waste generation process for different types of materials. Furthermore, conversion ratios are employed to aid contractors in calculating the weight and volume of materials and waste for transportation purposes. The waste levels of materials in each terminal work package are used to assess the waste produced by various construction processes. Consequently, the proposed waste estimation model combines the Mass Balance Principle (MBP), Material Quantity Take-off (MQT), material quantity take-off, conversion ratios across different waste measurement units, and the wastage levels of various materials utilized in distinct work packages.

Results and Discussions

Presentation and result

The results is presented in this chapter are based on tests carried out to assess the physical and mechanical properties of concrete made with partial replacement of cement with wood ash.

Physical properties of the research materials

Sieve Analysis

S*ieve analysis of fine aggregate:* Table 4.1 Present the results of sieve analysis of fine aggregate (sand) which was used to determine the fineness module as 2.5 According to Garba (2014) fineness module ranges from 2.0 -3.5 (_+0.2) and the value falls within the range. The percentage of the fine aggregate passing sieve 600 microns was 98.65 which is indicating that the fine aggregate fall under Zone 2 and can be used for construction (Gupta and Gupta. 2012).

Table 4.1 Sieve Analysis of Fine Aggregate

S//No	sieve size	Mass% of mass Retained	cumulative Retained Mass	% of Retained	Total % mass Passing
1.	2.00mm	- -	-	100	
2.	1.18mm	4.8	0.48	0.48	99.52
3.	600μ	8.70	0.87	1.35	98.65
4.	425μ	51.30	5.13	6.48	93.65
5.	300μ	117.30	11.73	19.12	81.79
6.	212μ	384.50	38.45	56.66	43.34
7.	150μ	384.00s	38.40	95.06	4.94
8.	63μ	42.8	4.28	99.34	0.66
9.	Collector	6.60	0.66	100	

Source: Laboratory Research Work (2025)

Sieve Analysis of coarse Aggregate: Table4.2: shows the results of sieve analysis of coarse aggregate. The fineness modulus of the aggregate was determined as 6.113.According to Gupta and Gupta (2012) fineness modulus ranges from 5.58.0 and for all in aggregate, between 3.5 and 6.5.

Table 4.2 Sieve Analysis of Course Aggregate

S//No	sieve size Retained	Mass Retained Mass	% of mass Retained	Cumulative % of Mass	Total % of Retained
1	28	-	-	-	-
2	20	432.5	28.83	28.83	71.17
3	14	869.7	57.97	86.8	13.2
4	10	167.4	11.16	97.96	2.04
5	5	30.6	2.04	100	-

Source: Laboratory Research work (2025)

Bulk Density and Specific Gravity of Material

Table 4.3 shows the specific gravity and bulk density of the aggregates, the specific gravity of the fine and coarse aggregate is 2.58 and 2.51 respectively. Which falls within the range of (2.5 – 2.9) as described by Duggal (2008). The bulk density of the fine and coarse aggregate is 1524.15kg/m^3 and 1597.15kg/m^3 respectively, which falls within the range of (650-1800kg/m^3)of lightweight concrete as described by Duggal (2008).

Table 4.3 Bulk Density and Specific Gravity of Material

Material	Bulk Density (kg/m^3)	Specific Gravity
Fine aggregate	1524.15	2.58
Coarse aggregate	1597.73	2.51
Cement	1210	2.42
waste agg.	831	2.13

Source: Laboratory Research Work (2025)

Quantities of Materials

Table 4.4 shows the quantities of materials used in producing 15 cubes of concrete specimen. Waste concrete was used to replace 5%, 15%and 25% by weight of the cement in concrete. Concrete with no used concrete serves as the control. The mix ratio used was concrete $1{:}1^{3}/_{5}{:}4^{4}/_{5}$ (blinder, sand and granite) which was designed with water/cement ratio maintained at 0.55. The details of the concrete mixtures used in the tests are listed below.

Table 4.4 Quantities of Material Used In Producing Cubes of Concrete Specimen

Percentage of	Cement (kg)	waste conc. (kg)	fine Ag.(kg)	Coarse agg.(kg)	Wood ash (%)
0	19.265	-	31.682	73	832
5	18.282	0.983	31.682	73	832
15	16.377	2.888	31.682	73	832
25	14.449	4.816	31.682	73	832

Source: Laboratory Research Work (2025)

Mechanical Properties of Concrete

Fresh Concrete

Slump test: Table 4.5 shows the relationship between slumps made with various percentage replacements of cement and the control specimen. W.A 5% and W.A 25%have slump values of 54mm, 51mm, 22mm and 15mm respectively. Sample A and Sample B falls within the range of 50-100mm) as described by Neville and Brook (2010) which represent a medium and true slump. While WA 25% falls within the range (0-25mm) as described by Neville and Brooks (2010) which represent slump, this is perhaps as a result of high percentage replacement of cement by waste concrete.

Slump Test

Workability	concrete specimen	Values (mm)	Degree of Workability
Slump (mm)	Control	54	Medium
	WA 5%	51	Medium
	WA 15%	22	Very low
	WA 25%	15	Very low

Source: Laboratory Research Work (2025)

Compacting Factor Test: Table 4.6 shows the relationship between factor result obtained from percentage replacement and that of control specimen. Control WA 5%, WA 15% and 25% has compacting values of 0.93, 0.92, 0.80 and 0.78 respectively. Control and WA 5% falls within the range of medium degree of workability as described by Neville and Brook (2010), while WA 25% falls within the range of very low degree of workability as described by Neville and Brooks (2010)

Table 4.6 Compacting Factor Test

Concrete Specimen	Weight of Partially compacted concrete	Weight of Fully compacted conc.(kg)	Compacting Factor	Degree of workability
Control	17.68	18.89	0.93	Medium
WA 5%	17.42	18.90	0.92	Medium
WA 15%	15.02	18.84	0.80	Very low
WA 25%	14.53	18.72	0.78	Very low

Source: Laboratory Research Work (2025)

Hardened Concrete

Water Absorption: Fig 4.1 shows the relationship between water absorption of concrete produced with partial replacement of waste concrete with cement. The water absorption of control at 7 days curing period was 1.06%. Likewise the water absorption for control at 28 days curing period was 1.633% which indicates that specimen Water absorption from 7 to 28 days curing period increase by % water absorption of WA 5% at 7days curing period was 1.925% and at 28 days was 2.780%which indicates that the specimen water absorption increased by 0.855% from 7 to 28days. Likewise, water absorption of WA

15% at 7days curing period was 2.157% and at 28days indicates a value of 1.974% which proof that the concrete specimen water absorption decreased decreasing by 0.183%. Sequently, water absorption of WA 25% at 7days curing period was 1.930% and at 28days indicates a value of 2.785% which proofs an increase in water absorption content of the concrete specimen by 0.855%.The values gotten are perhaps as a result of increase and decrease of some chemical oxide in the percentage replacement. (Robinson et. al...2014) stated that the average percentage of water absorption of concrete specimen shall not be greater than 5% at 28days curing period which indicates the percentage of water absorption is sufficient.

Findings

1. The control WA 5% WA 15% and WA 25% specimen produced had a percentage increase in strength of 17.84%, 21.24%, 49.13% and 38.79% at 28days respectively.

2. the bulk density of the fine aggregate, coarse aggregate, and cement used is 1524.15kg/m^3, 1597.15 kg/m$^{3 \text{ and } 1210}$ kg/m^3 Respectively.

3. The specific gravity of the fine aggregate, coarse aggregate and cement used is 2.58.2.51 and 2.42 respectively.

4. The slump value for control WA 5% WA 15% and WA 25% are 54mm, 51 mm, 22mm and 15mm respectively. Control and WA 5% falls within the range of (50-100mm) which represent a medium and true slump. While WA 15% and WA 25% falls within the range of (0-25mm) which represent a very low slump.

5. The compacting factor result obtained from percentage replacement and that of control specimen. Control, WA 15% WA 15% and WA 25% has compacting values of 0.92, 0.80 and 0.78 respectively. Control and WA 5% falls within the range of medium degree of workability.

6. The compressive strength of partial replacement of concrete with waste concrete at 15% at 28days was the closet to the control.

7. The percentage of water absorption of the concrete specimen was satisfactory.

Conclusion and Recommendations

The relevance of this research is to develop a model for recycling construction waste towards effective project costs control in Kebbi state**.**

The following conclusion can be drawn on the results and discussion of the study made:

Based on the research carried out the fine aggregate, coarse aggregate and cement were found to have a bulk density of 1524.15 kg/m^3, 1597.15 kg/m^3 respectively. And the specific gravity of fine aggregate, coarse aggregate and cement used is 2.58, 2.51 and 2.42 respectively.

The slump value of control WA 5% WA 15% and WA 25% are 54mm, 51mm, 22mm and 15mm respectively, and the compacting factor result obtained from control. WA 5% WA 15% and WA 25% were 0.93, 0.92, 0.80 and 0.78 respectively.

From grade 30 concrete designed, the mix ration was 1:1$^3/_5$: 4$^4/_5$ with water cement ratio of 0.55. The compressive strength of the percentage of the replacement as WA 5% WA 15% and WA 25% at 28days of curing was 16.074N/mm^2, 19.111 N/mm^2 and 16.074 N/mm^2, 19.111 N/mm^2 and 16.963 N/mm^2.

Based on the result obtained WA 15% concrete specimen has higher compressive strength compared to WA 5% and WA 25% specimens. The researcher drew the recommendation as follows:

It is recommended that the development of the concrete should be determined at a larger curing period from 56days and above. The concrete could be used where light loading is expected such as embankment. Strip footing and ordinary ground floor, floor slabs work due to its low compressive strength. Further study could be done on flexural strength and fire resistance of concrete produced with partial replacement of cement with waste material (concrete).Test on durability of properties could be carried out.

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