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Construction and Demolition Waste Management in Public Infrastructure Projects in Ghana: A Study in the Northern-Western Ghana.

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Abstract
Increased construction and infrastructure development in Ghana has meant increased C&DW, posing challenges to urban sustainability. Although the circular economy is increasingly acknowledged, in C&DW, there is scant practical applicability and regulation in many cities of Ghana. This research addressed the management of C&DW in Wa Municipality, Upper West Region, Ghana. This included the reuse of C&DW, the drivers of C&DW, constraints on the use of C&DW, the knowledge of infrastructure development regulations, and the barriers to the protection and preservation of sustainable development. Fifty construction professionals and tradesmen were selected for the research, and a quantitative design using surveys was employed. This was further supplemented by direct observations. Data were analyzed using descriptive statistics. The research found that 46% of the respondents reuse materials. The materials were tiles, metals, timber, and concrete. Reuse was mainly for temporary construction, infill, and artisanal purposes. Such reuse was informal and undocumented and led to a great deal of waste. This was attributed to poor management, inadequate measurements, and a workforce of mainly low skilled artisans. There was a significant lack of knowledge of regulations and enforcement in the municipality was noted as poor. The research proposed that the adapting of C&DW in Ghana could bring sustainable housing and infrastructure.
The primary suggestions regarding policy are; (1) implement focused capacity building initiatives for artisans and site managers, (2) revise the current laws to unambiguously reflect C&DW management, (3) provide specific financial incentives to aid contractors in the reuse of material, and (4) provide adequate infrastructure and guidelines to assist in the localization and sustainable C&DW recycling markets to help practice circular economy in construction.

Keywords: *Construction and Demolition Waste; Sustainable Infrastructure; Public Projects; Circular Economy; Urban Development; Ghana.*

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I. Introduction

Rapid urbanization in the Global South alters lifestyles and spatial practices, while simultaneously producing critical forms of environmental degradation. Population concentration in cities spurs demand for new housing, roads, civic and retail buildings and subsequent construction booms. New construction generates new jobs and positively contributes to economic growth. However, construction boom cycles generate large volumes of construction and demolition waste. Therefore, construction waste has become an impediment to sustainable urbanism.

For the past two decades, rapid urbanization and the growth of Ghana's population and construction industry along with an increase in public infrastructure and private real estate initiatives, has been a result of the shifts in the process of urbanization as described. Investments in housing, transportation, education, and health and administrative infrastructure have led to an improved spatial and functional organization of cities. Although these have advanced the goals of national development, they have increased the challenges of waste management and construction and demolition waste. In many developing countries, unmanaged construction waste contributes to visual blight, land degradation, flooding and infrastructural damage which increase the impact of climate change and threaten the very construction of a resilient urban system.

For an understanding of the composition and handling of construction and demolition waste (C&DW), reference (Lu & Yuan, 2012; Ajayi et al., 2015) among others. C&DW consists of concrete, masonry, metal, timber, tiles, plastics, soil, and packaging waste. These results from construction, renovation, and demolition processes. C&DW is among the largest waste streams, however, it remains among the least managed especially

in developing countries. Countries in sub-Saharan Africa including Ghana, have weak waste management systems that are largely fragmented and focused on waste disposal. There is little to no waste segregation at source or systems that promote the reuse or recycling of waste. C&DW is often disposed of in open and abandoned areas, water ways, informal landfills, and construction waste is burned in order to clear the construction site. This leads to waste of potentially valuable secondary resources and increased construction costs. Environmental pollution and public health issues are also a concern.

Waste disposal practices are also a concern beyond the loss of secondary resources. These practices limit the sustainability of the construction of infrastructure and housing and are a contradiction of the UN SDGs, especially with regard to the creation of safe and sustainable urban areas (SDG 11). The management of C&DW is critical to support sustainable development, climate resilience and efficient use of resources.

To transform waste into a resource, the circular economy has begun gaining popularity within the construction sector as a solution for some of the problems outlined. The circular economy focuses on reducing waste by minimizing the need for virgin resources through the reuse, recycling, and recovery of materials throughout the lifecycle of construction projects (Mahpour, 2018; Bayram & Greiff, 2023). Reusing or recycling construction and demolition waste can result in multiple end uses, such as sub-bases for roads, blocks, fill, and even landscaping. Efficient resource use in construction along with the above practices can help reduce detrimental impacts and effect cost savings.

While many advantages are associated with the circular economy, there are practical issues that will affect its implementation. The adoption of circular practices cannot be accomplished through technical feasibility alone. There are many interconnected issues that will affect the transition from a linear, disposal-based system to a circular construction model. Among others, these include the regulatory system, market drivers, professional and institutional capacities, and the social acceptance of reused materials. In many developing situations, the inadequate enforcement of regulations, a lack of standards and negative attitudes towards the use of secondary materials, and a poor recycling infrastructure will hinder the adoption of recycling and reuse initiatives. Thus, the use of C&DW is largely untapped.

Research about construction and demolition waste in Ghana has focused on major southern cities like Accra and Kumasi (Baidoo, 2016; Kareem et al., 2015), because services and governmental and business systems are relatively more developed there. Here, the urban-based studies have focused on waste generation and on the management and the policy frameworks related to it. Peripheral, less developed urban areas and the northern regions in particular have been largely ignored, even with the anticipated growth and investment in those areas. This peripheral focus makes it nearly impossible to understand the problems relating to the management of construction and demolition waste in the less urban areas that are resource and skill constrained.

This study attempts to address the research gap and study the Wa Metropolis, the capital city of the Upper West Region of Ghana, which has relatively recently become an urban area undergoing development of public infrastructure such as roads, housing, schools, and health facilities. Waste recovery and recycling are still lagging behind despite the development of public facilities. Construction in Wa Metropolis tends to be dispersed, informal, and unregulated, greatly increasing the likelihood of environmentally damaging construction. Therefore, this study seeks to understand the management of construction and demolition waste to aid the development of context appropriate, inclusive strategies for sustainable infrastructure.

This paper examines government projects in Western Australia to study the management of construction and demolition waste. Its objectives include: (i) identifying the dominant waste materials and their reuse practices; (ii) analyzing the causative factors of on-site waste; (iii) evaluating the level of compliance and knowledge of the waste management laws; and (iv) identifying the existing barriers to the optimal utilization of construction waste. This paper aspires to document the region's data to address the possibilities of the construction waste self-regulation and building design improvements and the people-oriented urban planning in the Global South. The findings provide recommendations to the policymakers and construction managers on the effective and sustainable resource utilization within the construction industry of Ghana.

II. Literature Review and Conceptual Framework

2.1 Construction and Demolition Waste and Urban Sustainability

Construction and Demolition Waste (C&DW) are some of the most rapidly growing waste streams in the world due to their intensive nature (Nasir et al., 2017; Saka et al., 2024). C&DW encompasses surplus and rejected construction materials and components, excavated earth and other wastes generated during the construction project life cycle including design, construction, renovation, and demolition. The largest waste streams are located in regions where rapid urbanization is present due to the need to build rapidly to accommodate the growing need for housing and infrastructure.

In the rapidly urbanizing regions of developing economies, C&DW have the largest negative impact and the largest structural challenges. These include loss of C&DW through informal construction practices, the poor enforcement of construction standards, inadequate planning, supervision and a weak construction workforce. Loss

of C&DW is further increased during construction through design changes of construction activities and poor material handling and planning. The result is that the volume of C&DW generated in the Global South is often greater compared to the volume in the Global North most developed economies, even when displacement is accounted for.

Uncontrolled C&DW negatively impacts the sustainability of urban environments. Environmentally, C&DW causes land degradation, disruption of drainage systems, flooding, soil contamination and greenhouse gas emissions. C&DW also destabilizes the community in urban areas of low population density due to dust, debris and areas for disease propagation. C&DW also negatively impacts the economic sustainability of urban infrastructure projects due to the loss of construction materials. The result is an even greater unequal environment for low income urban residents.

The performance of waste management systems and the delivery of urban infrastructure are interdependent. The absence of effective recovery, reuse, and recycling systems generates cumulative pressure on landfills, drainage, and municipal systems. Waste management, in such cases, is reactive to crises rather than preventive and strategic. The integration of construction planning, procurement, and site management, along with other systems, is seen increasingly as a fundamental component of the sustainable management of urban development and infrastructure systems. This is especially important for rapidly growing secondary cities in developing countries, where construction is booming but the systems are weak.

2.2 Usability and Circular Economy in Construction

Usability is the ability of waste materials to be recovered, remanufactured, and reintegrated into building processes without compromising the safety, performance, and quality of the building (Adesi et al., 2023). Many materials in the construction industry can be reused or recycled. Concrete debris can be used for road sub-bases or backfilling and for other non-structural applications. Metals can be reused or melted for fabrication. Timber can be used for formwork and for temporary structures, and tiles can be used for secondary finishes. These materials can, if optimized, be used in place of virgin resources, can be a cost reduction for construction, and can help reduce the environmental impact of construction activities.

Thinking from a circular economy provides a way of looking at construction waste as a resource rather than a detriment. Encouraging reduction, reuse, recycling, and recovery throughout the project lifecycle is the aim of circular construction. The impact of circular construction on sustainability is from a reduction in landfill diversion, a reduction in emissions of greenhouse gases, and a reduction in waste and resource consumption, and providing a stimulus for new businesses and keeping construction within the local economy.

Unlike developed countries, the implemented practices of circular economy approaches in construction in developing countries are scarce. Informal reuse practices in the construction sector of Ghana are usually uncoordinated and executed by individual construction artisans and small-scale contractors, with little being done by the established formal institutions (Agyekum et al., 2020; Ablordeppey et al., 2023). Construction professionals understand the idea of material recycling and the benefits of material recovery; however, several challenges limit material recovery in construction. These challenges are inadequate local recycling and processing facilities, a national policy vacuum for recycled construction materials, a lack of confidence and quality assurance in recycled construction materials, and inadequate capital for investment in recycling practices and technologies.

In developing economies, the social and cultural practices of communities have a significant influence on the recovery and reuse of construction materials. In some cases, the reuse of construction materials may be feasible and convenient, but clients and construction contractors prefer using new materials. When regulatory frameworks and certification systems are absent, the negative perceptions of clients and contractors favor undesirable linear construction practices that focus on disposal. Consequently, the sustainability goal of integrating usability of construction and demolition waste (C&DW) in the construction of new infrastructure remains widely unachieved.

2.3 Drivers of C&DW Generation and Management

From the literature, it is common to include aspects such as regulatory, technical, economic, socio-cultural, and institutional factors to describe the motivations/forces/drivers that shape the generation of construction/demolition waste and its management (Lu et al., 2011; Pitti et al., 2023). Regarding the regulatory factors, the existence of waste management policies and the presence of enforcement and incentive mechanisms for the reuse and recycling of materials are examples of regulatory factors. In the case of weak regulations or poor enforcement, construction companies are under little or no pressure to implement waste practices that are more sustainable.

Technical factors address the skill and associated knowledge of construction/demolition workers, as well as the existence of technologies for the sorting, storage, treatment, and reuse of construction/demolition waste. Poor technical capacity is usually associated with poor handling of construction materials, the absence of sorting on the construction site, and reliance on waste disposal.

The construction/demolition waste management market is influenced by the economic factors associated with the comparison of unit costs of virgin (new) vs. recycled (used) construction materials. When construction materials are cheap and easily accessible, the market has low incentives for the reuse of materials.

Socio-cultural factors are the perceptions associated with waste and the materials that are reused, as well as the acceptance of secondary products. This includes perceptions of quality, safety, and social status. Institutional factors include collaboration and coordination among construction companies, municipal authorities, regulators, and waste management companies.

In northern Ghana, restricted urban development, underdeveloped infrastructure, and a lack of skilled labor intensify the challenges. In most cases, assemblies lack the resources and know-how to properly supervise construction and adequately impose waste management rules. Consequently, Construction and Demolition Waste (C&DW) management is primarily concerned with the disposal, rather than the recovery and reuse of this waste. For developing fitting interventions, it is critical to identify, at the local level, how these dimensions converge.

2.4 Conceptual Framework

This research applies a framework that correlates construction practices, institutional capacity, and socio-cultural contexts. It investigates construction and demolition (C&D) waste and sustainable infrastructure delivery. Lots of waste is generated because of poor construction project planning, poor estimation of the required materials, low technical skills and poor site supervision. Weak enforcement of laws, poor coordination of the project stakeholders, and lack of incentives to implement construction and demolition waste (C&DW) practices to reuse and recycle constrain the practices. Negative attitudes toward the market of reused materials and the perceived quality of reused materials reinforce the use of newly manufactured (virgin) materials.

Construction waste can be reintegrated into construction processes where conditions are supportive and construction infrastructure is technically adequate, skilled personnel are available, and there is a supportive regulatory framework and market incentives. This supports circular construction and reduces construction waste, physical construction processes, and environmental impacts. C&DW management is positioned as a means of bridging the gap between vertical construction practices and the urban sustainability goals. Integrating the waste management processes with the planning and construction of infrastructure delivery systems will improve the resource efficiency, sustainability, and the environmental impacts of housing and infrastructure systems in the Global South.

III. Methodology

3.1 Research Design and Study Area

A quantitative research design was used to analyze construction and demolition waste (C&DW) management practices for public infrastructure projects in the Wa Metropolitan Area of Ghana's Upper West Region. The quantitative design was best for this project because measuring and comparing the C&DW generation and reuse, as well as the challenges to the C&DW management methods, can easily be done with a large sample of construction sector stakeholders. Furthermore, numerous statistical methods can be used to summarize the data and capture trends to answer the research questions.

Wa is a growing urban area and the capital city of the Upper West Region. The public sector has recently invested in construction of housing, roads, schools, and clinics as part of the national public sector development policy. This has increased construction activities, especially public sector construction, for small-and medium-sized contractors. There is an absence of formal construction waste collection, reuse, and recycling systems. The practices that currently exist are informal, and there are no adequate construction waste management regulations or sustainable waste management practices. For these reasons, Wa is a suitable location to evaluate the challenges of managing C&DW in the Global South, where urban growth is greater than the local government's ability to provide basic services.

3.2 Population and Sampling

Construction workers and tradesmen working directly on public infrastructure in Wa Metropolis were the focus of the study. Masons, carpenters, metal benders, site supervisors, and small contractors that do construction and/or demolition work would fall into this category. They handle construction/demolition materials, along with creating construction/demolition waste, and make the decisions as to the reuse of materials and how the site will be managed, therefore making them the right respondents.

Purposive sampling was the main technique used to select workers with the right experience in the area cited, while convenience sampling was used to select workers from building sites that were the least difficult to access. 50 respondents were chosen for this study. The sample size may be very small for some studies, but it is adequate for exploratory research in a case where there are almost no formal records on construction workers and access to building sites may be difficult. The sampling method used in the study gave construction respondents

the right experience in the construction activities cited, along with the management of construction waste. As a result the data collected was reliable.

3.3 Data Collection Instrument

Structured questionnaires were used to collect primary data during face-to-face interviews. As a result, data collection remained standardized and versatile for analysis. In the context of this study, face-to-face interviews allowed the researcher to provide clarification, adjust for respondents' literacy levels, and facilitate the accurate completion of the questionnaire.

The questionnaire was sectioned based on: (i) demographic information, (ii) types and sources of onsite construction and demolition (C&D) waste, (iii) practice of waste reuse and disposal, (iv) causes of waste, (v) knowledge of C&D waste regulations, and (vi) obstacles to the capability and practice of construction waste reuse. The majority of the questions were closed-ended. Measurable responses were given via a Likert scale or categorical options.

Field observations of construction sites were performed to substantiate the reported practices and survey responses. Materials storage, waste segregation and on site reuse, and waste disposal practices were the focus of the observations. This data was used to add context and support the information reported by the survey respondents.

3.4 Data Analysis Techniques

The data obtained from the questionnaires were analyzed, and basic statistics were applied. Frequencies and percentages were used to describe the characteristics of the respondents, the kinds of waste they produce, and their levels of awareness of the regulations. Mean scores and rankings were used to assess the importance of the perceived causes of waste generation and the perceived challenges to the usability of construction and demolition waste. The employed statistical techniques assisted the analysis of prevalent waste streams, current waste reuse practices, and the major challenges of the waste management process.

The analysis focused on recognizing and describing the issues in relation to the study objectives, so patterns rather than causes were the focus of the analysis. The major findings were summarized in tables and figures for ease of understanding and interpretation. The use of descriptive statistics was applied in this study in line with similar studies in the field of construction waste management, especially in studies that are of an exploratory nature and in which there is limited baseline data.

3.5 Ethical Considerations

Attention to ethical issues was constantly observed as a priority during the process of this research. Participants were free to opt-out of this study at any moment. Pertaining to the nature of this study, potential respondents were able to read a short notice explaining the study that was posted before data collection. This notice was designed to inform the respondents. Participants were then asked to give their informed verbal consent. As well, participants were provided the assurance of their study participation being anonymous and their responses being confidential. In this case, assurance of anonymity also meant that no personal identifiers were included in the analysis of data nor in the reporting of the results. All forms of data that were collected and used were honorable and in accordance with the ethical conventions governing to social and construction research for the sole purpose of informing academia and furthering research.

IV. Results

4.1 Respondent Profile

The demographic details of construction and building respondents help contextualize the generation and management of construction and demolition waste (C&DW) from public infrastructure projects in the Wa Metropolis. The data in Table 1 shows that the sample population comprised mainly males (90%), with females constituting the remaining 10%. The sample population gender distribution, the gender distribution of the construction workforce in Ghana and the results of the previous construction workforce studies (Asare et al., 2023) show construction and building trades in Ghana are male dominated. The low female representation in the construction workforce indicates that the gender gap in trades-based construction employment, and site-based construction trades in particular, are persistent.

The age data show that the majority of the respondents were within the economically active age group (18-45 yrs). The data suggests that the majority of construction workers in the Wa Metropolis are of relatively younger age. The implications of the data for the construction workforce in the Metropolis point to a relatively young workforce, the effect of which must be considered in relation to skilled workforce planning and the sustainability of the workforce. The younger workforce has the potential to undertake physically demanding work, and be easily adaptable, but the potential must be matched with planning and oversight in order to mitigate losses arising from poor work practices and material wastage.

Educational qualifications of participants ranged from having no formal education to holding a degree for citing higher education. Table 1 presents a summary of respondents' education levels: 24% had completed Senior High School, and 22% had no formal education. Respondents with higher education were 20%, primary education sampled 18%, and Junior High School education were 16%. The majority of respondents sampled had an education level of primary or secondary school. Wastes minimization, material optimization, and sustainable construction practices are highly depend on advanced levels of education and/or professions. Due to the focus of this study, the respondents' levels of education may hinder their understanding of the construction practices being researched.

Regarding years of work experience, 70% of respondents had less than 10 years, while 30% had 10 or more years of experience. This indicates that artisans with little experience dominate the construction sites of public infrastructure projects in Wa Metropolis. Lack of experience may result in poor construction practices and may contribute to waste on the construction site. Overall, the respondents may help explain the construction practices and/or the management of construction and demolition waste in the area.

Table 1: Demographic Characteristics of Respondents

Variable	Category	Frequency	Percentage (%)
Gender	Male	45	90
	Female	5	10
Education	No formal education	11	22
	Primary	9	18
	JHS	8	16
	SHS	12	24
	Tertiary	10	20
Experience	Less than 10 years	35	70
	10 years and above	15	30

4.2 Types and Sources of C&DW

The main construction waste included all forms of concrete and masonry debris, metal offcuts, timber, and packaging waste. Poor onsite storage, rework, design changes, poor measurement, low-skilled labour, and poor supervision were the main drivers of waste generation.

Table 2: Key Construction and Demolition Waste Types

Waste Type	Frequency	Percentage (%)
Concrete and broken blocks	42	84
Tiles	31	62
Timber offcuts	28	56
Metal scraps	25	50
Packaging materials	21	42

The research outlined different categories of construction and demolition waste generated by public infrastructure project sites in the Wa Metropolis. Data in Table 2 illustrates the prevalence of concrete and broken block waste of which 84% of respondents captured in the survey. This was trailed by waste of tiles (62%), timber offcuts (56%), metal scraps (50%), and packaging waste (42%). The project waste streams captured in the survey indicate the public infrastructure projects incorporate construction materials of concrete and masonry, timber, and finishes.

Respondents listed the main contributors to concrete and block waste as the over-ordering and breakages of construction materials during and post transportation, and construction errors which create the need for rework. Poor formwork practices and site supervision were also waste contributors, as they lead to the demolition of Constructed Defective Formwork. Waste of tiles was the result of breakage during the installation, poor storage, and waste of timber from formwork and poor planning of the timber as a construction resource.

Waste of metal scraps was from cutting and fabrication of reinforcement where poor measurements and designs during construction resulted in waste. Packaging waste was made up of cement bags, packaging wastes of plastic and cardboards, which were also generated wastes and were neither reused nor recycled. The main

construction waste contributors were poor site practice, poor storage, estimation and design, low skilled or unskilled labor, and poor site supervision which all indicate that construction waste can be mitigated from better management and planning of the site.

4.3 Reuse Practices and Applications

Table 3: Reuse Practices and Applications of C&DW

Waste Material	Reuse Application	Percentage (%)
Concrete debris	Foundation filling / road sub-base	46
Metal waste	Fabrication / artisanal works	38
Timber waste	Formwork / temporary structures	34
Tiles	Secondary finishes	22

Results show that construction waste reuse practices are infrequently applied within public infrastructure projects in Wa Metropolis. As shown in Table 3, 46% of respondents reported reusing construction waste, while 54% did not report reusing construction waste. From the data, it can be inferred that reuse practices are infrequently adopted and waste disposal practices are preferred.

In responding participants, reuse of construction waste mainly involved the reuse of concrete debris, which was used to fill foundations and construct road sub-bases. As concrete in crushed form meets the requirements for fill in non-structural (low) construction, the technical requirements are also low. Waste metal was reused by 38% of respondents for fabrications and hand works (artisanal work). These included gates, grills, and minor elements of metal work. Waste timber was reused by 34% of respondents in the construction of formworks and other temporary structures. The reuse of tiles for secondary finishes was reported by 22% of respondents.

Many of the respondents from whom the data was obtained reported that the factors that deter formal reuse practices in the construction waste among the public infrastructure projects include inadequate technical knowledge, lack of time, no recycling facilities, and low market demand for the reused construction materials. These data imply that the factors that deter institutional reuse practices are economic and technical in nature.

4.4 Awareness of Regulatory Frameworks

Most people did not know there are already metropolitan or national regulations about C&DW. Where there was knowledge about the regulations, weak enforcement and limited monitoring of compliance were reported.

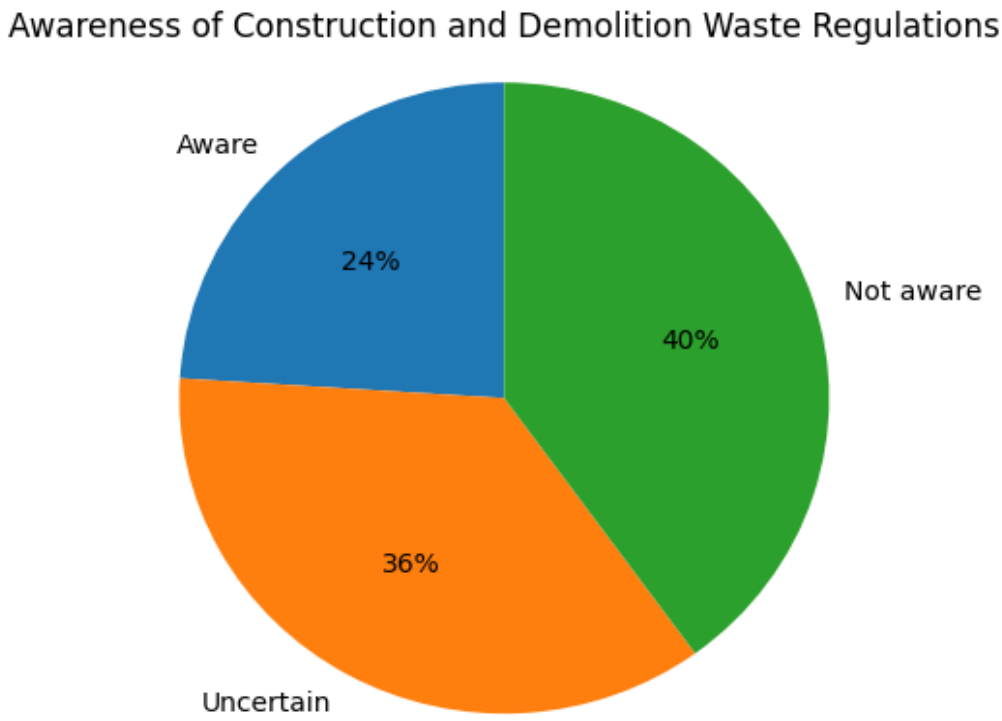

Figure 1: Awareness of C&DW Regulations among Respondents

Respondent awareness of construction and demolition waste management regulations was generally low. Figure 1 shows that 40% of respondents thought C&DW was unregulated, and 36% were unsure of the existence of any such regulations. Only 24% of respondents were aware of any construction waste management regulations at the metropolitan or national levels.

This level of awareness indicates that the gaps in the communications and regulatory dissemination, as well as enforcement, at the metropolitan levels are significant. Respondents who were aware of any regulations reported weak regulatory enforcement. Compliance monitoring was described as absent or very limited. This indicates that, in the Wa Metropolis, if any regulatory frameworks do exist for construction and demolition waste management, they have very little or no impact on waste management practices at the construction and/or demolition sites.

4.5 Barriers to Effective Usability

Main barriers consisted of unavailability of training, absence of recycling units, less market demand for reusable materials, perception of low quality, collaboration barriers of metropolitan authorities and contracts, and lack of economic stimulus.

Table 4: Barriers to C&DW Usability (Mean Ranking)

Barrier	Mean Score	Rank
Lack of training and technical skills	4.52	1
Absence of recycling facilities	4.41	2
Weak enforcement of regulations	4.28	3
Negative perception of reused materials	4.12	4
Lack of financial incentives	3.96	5

Respondents reported multiple barriers that limit the feasibility and reuse of construction and demolition waste. The barriers are ranked and scored in Table 4. The greatest barrier was the absence of training and technical skills, ranked 1 and with the highest mean of 4.52. This was followed by the absence of recycling and processing facilities (mean = 4.41), weak enforcement of regulations (4.28), negative perceptions of reused materials (4.12), and lack of financial incentives (3.96).

This indicates that capacity-related barriers and institutional barriers are the most important constraints to C&DW usability in Wa Metropolis. The absence of recycling facilities limits the processing of materials, and weak enforcement of the regulations fails to encourage contracting personnel to adopt sustainable practices. The negative perception of reused materials further decreases demand and encourages the use of virgin materials. These barriers combined further prevent a change from a disposal-oriented waste management system to circular construction on public infrastructure projects.

V. Discussion

The results show that in the Wa Metropolis, like in most of Ghana, the main approach to C&DW management is disposal rather than recovery. Similar disposal-oriented systems are evident in most metropolitan and municipal waste management in Ghana (Ablordeppey et al., 2023; Bavuno et al., 2023). Artisans and site workers do engage in some informal, unplanned, and ad-hoc reuse of construction waste, but mainly at their own discretion. In the absence of formal systems for the segregation, storage, and recovery of waste, reuse remains at an informal and small-scale level. This is consistent with the other remaining construction sectors in Ghana, where there is increased advocacy for circular economy systems and construction waste management within policies and scholarly work, but there is limited engagement and implementation at the construction level.

Of increasing concern in the Wa Metropolis is the lack of technical skills and the inability to plan and supervise construction work. This is especially the case with the large pool of relatively unskilled or inexperienced construction workers. This leads to the pervasive loss of building construction materials because of poor execution of construction work, the use of imprecise measurements, and poor management of construction materials. This results in the waste of construction materials and the failure to use resources efficiently. These findings reinforce the evidence that a construction workforce with a high degree of competence is needed to reduce construction waste and improve the sustainability of the construction industry. Where there are limited opportunities for upskilling and the enforcement of poor professional standards, construction processes are wasteful and detrimental to socioeconomic and environmental development.

Apart from the technical aspects, C&DW management results are affected by socio-cultural aspects. The use of reused or recycled construction materials has been met with resistance from contractors and clients. This is due to the perception of recycled construction materials being lower in quality, less durable, or having higher

safety concerns. This resistance is despite the adequate technical performance of recycled materials. This shows that perception and socio-cultural issues are concerned with the construction material choice. In the absence of assurance, certification, and regulatory frameworks for the quality of reused materials, the perception of construction stakeholders will remain concerned and will impact the market of recycled construction materials.

Along with socio-cultural constraints, there are also institutional constraints that affect construction and demolition waste management. These are the low levels of regulatory awareness among construction stakeholders, along with the weak enforcement of regulations by metropolitan authorities. In the absence of clear regulatory frameworks and control mechanisms that provide a stimulus for the use of recycled construction materials, construction stakeholders are not motivated to invest in the segregation and sorting of construction and demolition waste. Therefore, the reactive management of C&DW continues to exert pressure on urban drainage and services.

When looking at the findings as a whole, the results suggest a failure of socio-cultural and institutional governance systems combined with a lack of skill development, and not simply a technical problem, is responsible for the persistence of disposal-based C&DW management. Without comprehensive placement of strategies to tackle these interlinked issues, construction waste will continue to overwhelm urban infrastructure, undermining the goals for sustainable housing and infrastructure in Ghanaian cities. The findings highlight the necessity for comprehensive strategies targeting the construction sector that encompass skill development, regulatory changes, and market development, as well as public awareness campaigns, to successfully implement the practices of the circular economy.

VI. Implications for Sustainable Infrastructure Development

The value added by increasing the potential uses of construction and demolition waste (C&DW) can provide an alternative means of positively impacting the sustainable delivery of infrastructure in Ghana. It can also, on a wider scale, support multiple international and regional development initiatives. These include Sustainable Development Goal 11 (SDG 11) and the African Union's Agenda 2063. SDG 11 promotes the development of sustainable and resilient human settlements and safe and inclusive cities. In turn, the African Union's Agenda 2063 expresses the vision for African cities to be centers of economic productivity with the sustainable provision of development and services.

In particular, substantive training of artisans, construction site managers, and small-scale contractors aligns with SDG 11.3, which speaks to the transformation of urban areas and the sustainable improvement of the planning and management of settlements. Construction efficiency and the generation of waste from construction activities can be enhanced by the training of site managers in the planning and supervision of construction activities. This type of training can also improve the safety and resilience of the constructed infrastructure. Finally, training of this type meets Aspiration 1 and Aspiration 6 of Agenda 2063, which supports sustainable development and inclusive growth across the continent and the investment in human resources, respectively.

Second, in the context of SDG 11.6, the integration of waste recovery and reuse in public procurement and contract documentation for infrastructure projects reduces the impact of urbanization on the environment through effective waste management. Public procurement is an important lever for circular economy policies in construction. By incorporating waste management plans, reuse targets, and reporting requirements into public contracts, urban authorities can promote accountability and environmental improvement and demonstrate their commitment to the provision of sustainable infrastructure. This also corresponds to the strengthening of systems and institutions of sustainable urban planning in the Agenda 2063.

Third, the provision of financial incentives and the establishment of pilot recycling and recovery plants support the economic and environmental objectives of SDG 11 and Agenda 2063. The creation of local markets for the provision and sale of recycled and reused construction materials diminishes the need for new resources, lowers construction costs, and creates green jobs. This supports SDG 11. a, which promotes positive integration of economic, social, and environmental networks and systems of the urban, peri-urban, and rural areas and Agenda 2063, which focuses on the provision of environments that support sustainable and climate resilient economies. In developing urban centers, such as Wa Metropolis, the provision of local recycling plants promotes regional development and reduces disparity in development through recycling.

Fourth, for SDG 11.1, establishing clear regulatory frameworks, guidelines, and certification systems for construction material reuse is important. For construction materials to be reused, there needs to be a mechanism to certify that the materials will be safe and will perform. This will give contractors, clients, and regulators confidence. Moreover, clear regulations will fulfill part of Agenda 2063 concerning safe and sustainable uses and management of the lands of Africa. Construction activities should not compromise the safety of the environment and the people.

Lastly, the safe and sustainable social development articulated in SDG 11 and Agenda 2063 will require education and engagement of all stakeholders. To reuse construction materials will require an intervention to shift the negative socio-cultural perceptions about them. Public education and stakeholder engagements are interventions that adhere to SDG 11.3's concern of participatory and inclusive governance. Other actors that will

develop the safe and sustainable urban environments envisioned in Agenda 2063 are professional bodies, community stakeholders, and civil society organizations.

To address the management of construction and demolition waste in everyday operations will meet the spirit of SDG 11 and Agenda 2063 in the context of Ghanaian cities. This will diminish the negative impact construction activities will have on the environment, make land use and drainage systems more effective, and make housing, and infrastructure more resilient and inclusive. Furthermore, C&DW management is in agreement with Ghana's goals of development and will promote a more urban resilient environment.

VII. Conclusion

This study focused on the management of construction and demolition waste (C&DW) in public infrastructure projects in the Wa Metropolis of Ghana, a developing area undergoing substantial housing and infrastructure investments. Although reuse of construction waste occurs, the research found this is mainly informal and uncoordinated. Where reuse occurs, it is mainly the result of personal choice, rather than a formal system or market. Due to these reasons, the potential of C&DW toward improvement of infrastructure sustainability has yet to be realized.

Additionally, this study shows the various ways in which C&DW is generated in the Wa Metropolis. It also shows how C&DW is influenced by a mix of technical, institutional, economic, and socio-cultural factors. Among these factors, poor planning and estimation have a large impact on the waste generated. Other factors include a poor understanding of waste management regulations and a poor waste management enforcement system. Further, there is a negative view of C&DW among contractors and clients which encourages the use of new materials. C&DW management requires an understanding of the full extent of the issues and not the self-contained and fragmented issues.

Reframing construction and demolition (C&D) waste as a resource, rather than a burden, is essential for the promotion of sustainable housing and infrastructure delivery in Ghana. A C&D waste circular economy perspective identifies room for the reduction of the consumption of construction materials, the cost of construction, and the negative effects on the environment, all while improving the resilience of cities. However, the construction sector requires a great deal of coordinated effort to implement the circular economy system successfully. Policies and regulations need to change to create transparent rules, as well as incentives and consequences. Developing the market requires a recycling system and other financial supports to make the reused construction materials affordable. There are also the required skills of the construction management team to minimize the waste the construction generates and control the construction materials better. Breaking the existing socio-cultural barriers requires a public awareness campaign, certification, and engagement of the various stakeholders.

This research provides the first empirical evidence of construction waste management in the secondary cities of the Global South. Based on case study evidence from a northern Ghanaian city, this research paper describes the importance of context-sensitive approaches for the less urbanized areas of the Global South that have lower institutional capacities. The research has a direct impact on metropolitan construction management policies for metropolitan managers and practitioners that help achieve their country's national sustainability agenda and help achieve the sustainable development goal (SDG 11) and the 2063 agenda of the African Union.

Subsequent studies should compare construction waste management across metropolitan and municipal areas of Ghana by including them in the study's scope. Multiple studies have the potential to enumerate waste and assess recovery potential using construction waste audits and material flow analysis. Additional studies should focus on waste management policies and the role of metropolitan assemblies, construction regulators, and construction professional associations in order to understand the construction waste management governance challenges. In Ghana's rapidly urbanizing cities, the evidence-based and research-based practices of sustainable circular construction will be more effective.

VIII. Contribution to Knowledge

This study has multiple theoretical implications for construction and demolition waste management, the circular economy, urban sustainability in the Global South, and beyond. First, it has implications for the socio-technical and institutional framing of construction and demolition waste management, as opposed to the socio-technical and operational framing of waste management. The study extends existing waste management theories by empirically demonstrating that technical capacity, regulatory governance, socio-cultural perceptions, and market structures affect the outcomes of waste management.

Second, the study has implications for the circular economy in construction and demolition waste, as it has shown that there is a significant gap between the ideals of circular economy practices and the actual practices of circular economy within developing urban contexts. The assumptions within the circular economy frameworks which place enabling institutional structures, developed market structures, and formal construction systems within the circular economy, do not apply to the case of Wa Metropolis, where circularity is the result of informal structures, incomplete skill sets, and inadequate regulatory frameworks. The findings of this research contradict

the assumptions of the circular economy and place the informal frameworks of the Global South in the context of circular economy practices.

Third, this study has integrated the emerging-city dynamics of the Global South into the relatively new field of urban sustainability and infrastructure development. This research has the potential to extend the theories of urban sustainable infrastructure and construction waste management by exploring the advanced institutional, peripheral urban, and rapidly developing urban environments of the Global South.

Finally, the study provides a conceptual contribution by interlinking empirical research concerning SDG 11 with Agenda 2063 to serve as analytical, rather than simply normative, frameworks. By using construction waste governance, the study shows how both the global and continental sustainability agendas can be practiced at the project and municipal levels. The study provides a theoretically grounded approach that links the construction practices of the project and the sustainability transitions of the municipality, and serves as the basis for the development of future theories on circular construction, institutional capacity, and urban resilience of the Global South.

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