

Investigating C&D Waste Recycling Enterprises Under Circular Economy in Developing Countries.

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Abstract - Construction and Demolition Waste Recycling Enterprises (CDWREs) face challenges within the circular economy framework in developing countries. This study highlights key obstacles such as market competitiveness, operational inefficiencies, and regulatory barriers. CDWREs often encounter higher costs and lower product awareness compared to traditional material producers. Additionally, they face difficulties due to inadequate waste collection and sorting infrastructure, coupled with a lack of investment in modern recycling technologies. These problems are further compounded by inconsistent government regulations and complex permitting processes, which hinder the growth and sustainability of CDWREs. Adopting a circular economy framework greatly enhances resource efficiency by reusing materials from construction and demolition. This reduces the reliance on virgin materials, conserves natural resources, and lowers carbon emissions from raw material extraction. It promotes sustainable waste management by minimizing landfill use and pollution. The circular economy also drives innovation and economic growth, increasing demand for recycled materials and fostering new technologies that improve recycling efficiency and product quality. This creates new market opportunities, enhances competitiveness, and generates jobs, supporting broader environmental and economic goals.

This research emphasizes the potential for improvement through targeted government interventions, technological advancements, and public awareness. Clear regulations, financial incentives, and streamlined permits can support CDWREs. Investment in advanced recycling technologies and public education can enhance efficiency and demand, helping developing countries achieve sustainability and circular economy goals.

Key Words: Circular Economy, Recycling Enterprises, Construction and Demolition, Waste Management.

1. INTRODUCTION

Infrastructure development significantly influences a country's economic landscape, with the global construction sector projected to grow at an annual rate of 3.6%, surpassing overall economic growth rates. However, the construction industry contributes to 50% of global solid waste due to its "take-make-dispose" approach [1]. To

mitigate the environmental impact, governments are formulating guidelines for recycling and reusing building materials. Managing Construction and Demolition (C&D) waste is complex, involving disposal and recycling. Inadequate waste management leads to land degradation, resource depletion, and pollution. Efficient C&D Waste Management (CDWM) practices, prioritizing recycling, reduce the demand for natural resources and mitigate greenhouse gas emissions, aligning with sustainability goals.

The circular economy, promoting sustainable production and waste minimization, views C&D waste as a valuable resource. This model suggests that waste should be reused, generating economic value. However, integrating circular economy principles faces challenges, including high costs. Despite this, the circular economy's 3R principles (Reduce, Reuse, Recycle) are essential for sustainable CDWM. Recycling C&D waste can create jobs, stimulate economic growth, and reduce landfill use.

CDWREs play a crucial role in transforming waste into valuable products, although they face challenges such as lack of regulatory guidance and short-term profit focus. Developing countries like China and India generate significant C&D waste, with most ending up in landfills due to ineffective practices and policies. In contrast, some developed countries are successful in diverting waste to recycling facilities.

Effectively managing C&D waste is crucial, especially in developing countries with inadequate sustainability practices and formal recycling systems. There is a need for increased awareness and planning for CDWRE development within the circular economy framework to enhance resource recovery and sustainability in the construction sector.

1.1 Research Aim

This research aims to investigate the barriers and provide developmental strategies for effective progression of CDWRE in the micro-environment of circular economy in developing countries. There are limited number of research papers that concentrate on CDWREs in developing countries. The results of this study can be utilized by industry stakeholders, policymakers, and regulatory authorities to progress and implement recycling waste management plans and facilitate

the transition of the construction waste management system to a circular economy from a bottom-up perspective.

1.2 Research Significance

The findings of this research have the potential to facilitate the exchange of knowledge between developing countries that are confronted with similar waste management issues in the recycling enterprise sector. The successful strategies and procedures could be disseminated to facilitate the implementation of circular economy practices in a timely approach. The research results can be used to provide evidence-based guidance to policy makers, regulatory bodies, and other relevant stakeholders in developing countries to proceed the development of effective waste management strategies. These strategies can promote circular practices and resolve waste management issues.

2. Literature Review

Construction waste management may be transitioned from the bottom up to a circular economy through the operations of CDWREs throughout the corporate micro-environment and the provision of improvement plans in the operation and market circumstances [1]. The current utilization of products derived from recycled construction waste is low, and most stakeholders hold constrained and unfavorable views of Construction & Demolition waste recycled products (CDWRPs), which deters the products from actively participating in decision-making processes through circular economy [2].

The circular economy has transitioned to a CDWM model where CDWREs seeks to generate value by using construction site waste as a primary resource for new product creation. [3] analyzed those impurities found in C&D waste can detrimentally affect the durability and strength of recycled products, thereby impacting their market value. Virgin material producers maintain a dominant market position due to their large scale, extensive production expertise, and established client relationships, ensuring financial stability and consistent services. Aside from price, CDWREs do not significantly outperform mature virgin materials.

[4] investigated that restricted waste acquisition and residue treatment options within CDWREs, often due to insufficient facilities and equipment, enable unregistered CDWREs to avoid regulatory scrutiny. Registered firms encounter heightened competition for cost-effective, high-quality C&D waste, making it difficult to procure premium raw materials. Consequently, CDWREs frequently struggle with the challenge of obtaining costly C&D waste containing substantial contaminants, resulting in increased processing costs.

By establishing a closed-loop recycling system for C&D waste can reduce intermediary profits while promoting self-production and self-sales. The strategic placement of a continuous manufacturing line minimizes transportation expenses. Collaboration with both upstream and downstream industries enable CDWREs to create an integrated closed-loop industrial chain encompassing dismantling, transportation, and processing, thereby alleviating financial constraints.

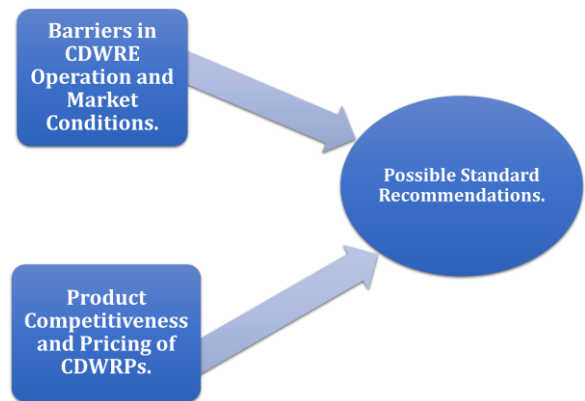


Fig -1: Comprehensive Conceptual Framework

3. Results and Discussions

3.1 Identified Barriers in CDWREs Operations.

Code	Barriers
B1	Lack Of Product Knowledge
B2	Lack Of Effective Marketing Strategy
B3	Hesitancy To Adopt Recycled Products
B4	Lack of Spacious Storage and Processing Facilities for Large Volumes of Waste
B5	Exorbitant Operating Costs and Stakeholders' Behaviour

Table 1: Barriers Influencing CDWREs Operation and Market Conditions.

3.2 B1- Lack of Product Knowledge.

Organizations engaged in marketing and distributing products derived from recycled construction materials occupy downstream positions in the industry chain. The current deficiency in a unified platform providing accessible information about these recycled products contributes to low consumer awareness regarding their availability and benefits. Limited public acceptance and unfavorable perceptions of recycled products present significant barriers to sustainable construction. The market for recycled products is still emerging, raising significant concerns about

availability, after-sales support, and resale value. Organizations worry that using recycled materials could complicate their supply chains and impact product quality standards, causing reluctance to adopt these materials. This issue is further exacerbated by inadequate consumer awareness of recycled products. Additionally, these challenges are compounded by inefficient information management among stakeholders, resource and technology constraints, non-standardized procedures, divergent objectives, and decentralized operations [5].

3.3 B2- Lack of Effective Marketing Strategy.

The progress of the circular economy and CDWM is hindered by poor coordination of information, resources, and investments. Companies often overlook competition, market dynamics, and business processes. CDWREs rely on ineffective traditional marketing methods, like deploying sales representatives with brochures to construction sites. As a result, these organizations encounter challenges in accessing proper distribution channels and establishing partnerships with retailers or wholesalers, mostly due to their limited marketing resources. Not utilizing suitable communication channels or failing to connect with consumers through their preferred mediums can restrict the reach and impact of marketing campaigns. This strategy fails to address sluggish sales due to limited product value, flawed marketing, lack of technical guidance, insufficient investment, and poor market insights. Additionally, inadequate understanding of customer needs prevents precise marketing and thorough feedback research [6].

3.4 B3- Hesitancy to Adopt Recycled Products.

Despite global government policies promoting recycled products, concerns about supply and demand hinder market acceptance. Different capabilities among construction stakeholders and consumer prejudice against recycled products, perceived as inferior to new ones, further impede acceptance. Enhancing stakeholder understanding can help eliminate these biases [7]. As per customer perception even though there is a growing preference for sustainable products, this preference narrative does not always translate into purchasing decisions of the recycled products. This entire disconnect emphasizes the need for recycling enterprises to invest in strong marketing strategies that not only raise awareness but also effectively persuade consumers of the tangible benefits and comparable quality of recycled products.

3.5 B4- Lack of Spacious Storage and Processing Facilities for Large Volumes of Waste.

C&D waste management requires specialized infrastructure, including sorting, crushing, and screening facilities with loading capabilities, demanding substantial space. In urban areas, CDWREs need significant capital investments for large

storage and processing facilities. The CDWM system faces obstacles due to limited interest and insufficient investment in these essential storage facilities [7]. Insufficient investment in waste management infrastructure by both governments and private entities results in inadequate facilities to effectively handle growing waste volumes. Additionally, outdated waste processing technologies restrict the efficiency and capacity of existing facilities, complicating the management of large amounts of waste. There are various complex permitting processes and zoning restrictions which delay the construction of new facilities or the expansion of existing ones. Private investors may also be hesitant to invest in waste management infrastructure due to perceived risks and uncertainties in the market. Interestingly, integrating public-private partnerships (PPPs) is a viable solution as PPPs can mobilize private sector resources and proficiency to balance public sector efforts, leading to more efficient and effective C&D waste management solutions. Successful examples from various countries have demonstrated that when governments and private entities collaborate, they develop state-of-the-art facilities that substantially enhance waste processing capabilities.

3.6 B5- Exorbitant Operating Costs and Stakeholders' Behavior.

Maintaining a continuous flow of C&D waste is crucial for long-term recycling. Inconsistent waste sources and significant investments threaten revenue stability and market feasibility. Increased waste volume raises transportation demands and costs also limited government resources hinder regulation enforcement. Contractors' reluctance to buy recycled products is influenced by policies, control, efficacy, societal norms, and information [8]. Stakeholders frequently prioritize short-term financial gains over long-term sustainability benefits, declining to support for recycling initiatives. Majorly because the preliminary setup costs for recycling facilities can be formidable, establishing a new recycling plant requires significant capital investment, including land acquisition, construction, and the purchase of specialized equipment. The regulatory environment also plays a role in shaping stakeholders' behavior. In some regions, there are insufficient government incentives or support for recycling initiatives. For instance, subsidies, tax breaks, or grants that could improve offset the high costs of recycling are often lacking. Additionally, complex, and bureaucratic regulatory requirements can further increase operating costs and delay project implementation, discouraging investment in the recycling sector. Stakeholders are hesitant to adopt new recycling methods due to the apparent need for substantial financial investments in establishing new recycling facilities. This perception arises from the expected expenses related to procuring and installing specialized equipment, introducing new processes, and possibly providing training for staff members.

4. Challenges in Product Competitiveness and Pricing of CDWRPs (*Construction & Demolition waste recycled products*)

Code	Challenges
C1	Waste Acquisition and Residue Treatment
C2	Lack of Technical and Operational Obstacles
C3	Dominance of Virgin Materials
C4	Recycled Product Quality

Table 1: Challenges in Product Competitiveness and Pricing of CDWRPs.

4.1 C1- Waste Acquisition and Residue Treatment.

The growing volume of construction waste challenges urbanization, increasing site accumulation and costs. Effective management requires minimizing waste at its source and efficient sorting, yet landfill exhaustion and resource strain persist. Unsystematic collection, poor transportation, and underdeveloped recycling technologies hinder market development [6]. The lack of sufficient equipment and site availability poses challenges in accessing limited waste acquisition channels, enabling unregistered CDWREs to bypass government oversight. Intense competition for high-quality, cost-efficient construction and demolition waste further complicates the ability of registered enterprises to secure superior raw materials. Significant challenges in recycling construction and demolition (C&D) waste. Collected waste often includes contaminants and mixed materials, complicating recycling efforts. Insufficient collection systems result in minimal recyclable waste. In India, up to 25% of C&D waste is non-recyclable, requiring additional sorting or ending up in landfills. High costs of collecting, sorting, and transporting waste diminish recycling profitability. Fluctuating supply and demand for construction waste complicate planning for recycling businesses. Proper segregation at the source is crucial, but often lacking, leading to mixed waste streams that are costly to separate and reduce recycling efficiency.

4.2 C2- Lack of Technical and Operational Obstacles.

Integrating circular economy principles into construction projects is crucial for environmental and technical advantages of recycled products. Additionally, there is a low level of awareness about recycling enterprise's potential to manufacture products meeting certified quality standards and inadequate training. According to CDWREs, the main operational challenges stem from the inconsistent flow of C&D waste, high expenses associated with its treatment and recycling, and the low discharge fees. CDWREs faces general financial constraints with fixed costs, such as site rentals and

employee wages, persist despite extended repayment cycles and ensuring financial stability is a significant hurdle. Since many CDWREs primarily depend on self-funds, it is challenging to manage cash flow disruptions, particularly as costs rise while sales decline [2]. Redundant equipment often requires more frequent maintenance and is prone to breakdowns, resulting in increased downtime and repair costs. This not only disrupts operations but also adds to the overall operational expenses. Advanced multi-material recycling systems can process a wider variety of materials simultaneously, improving recovery rates and reducing waste sent to landfills. Inadequate training for workforce engaged in recycling enterprises direct to operational barriers and less-than-optimal performance. Inefficiencies and errors result from inadequate staff training, which leads to higher operational costs. Plus, these costs include not only the direct expenses associated with equipment repair and material loss but also the indirect costs related to lower productivity and increased waste.

4.3 C3- Dominance of Virgin Materials.

Without robust research and strategies, recycling enterprises struggle to deliver competitive products, favoring companies producing virgin materials and hindering the circular economy. Recycled products face pricing disadvantages due to high recycling costs and limited awareness. The abundance and cost-effectiveness of virgin materials reduce demand for recycled alternatives, despite their recognized benefits and compatibility with standard construction practices [9]. Regulatory frameworks that lack incentives for recycled materials may maintain the dominance of virgin materials by failing to encourage their adoption in industries. This absence of prioritization hinders market demand for recycled alternatives, perpetuating reliance on virgin resources.

4.3 C4- Recycled Product Quality.

The lack of technical standards hinders quality control and product performance verification in recycling. CDWREs face high costs from impurity-laden C&D waste, requiring significant investment in processing. Reuse challenges include lead times, costs, and quality reliability. Contaminants if not segregated properly it can disrupt manufacturing processes, leading to defects or failures in product manufacturing or the final product. At times, recycled materials undergo a reduction in quality, known as downcycling, where the recycled product is of lower quality and functionality than the original material this situation can develop trust issues among stakeholders. This downcycling can limit the application of recycled materials to lower grade uses, making them unsuitable for high-performance applications which can disrupt the image of the recycled products. This contamination necessitates additional processing and quality control measures to ensure the product meets required standards. Insufficient returns from

recycled materials, high expenses, and impurity detection issues lead to narrow profit margins. Advanced technology and improved standards are essential for full construction waste reutilization [6]. Balancing the meager profits from recycled materials against the high costs of rentals, transportation, labor, and the challenge of detecting impurities presents a persistent challenge. This delicate equilibrium often leads to slim profit margins and, in some instances, the closure of recycling enterprises.

5. Recommendations for Possible Standards and Solutions.

Table 3: Possible Standards and Solutions.

Code	Recommendation
R1	Closed Loop of Waste Acquisition and Recycling Framework
R2	Strengthening Technological Innovation
R3	Expanding Product Types and Market
R4	Governmental Interventions
R5	Public Private Partnership

5.1 R1- Closed Loop of Waste Acquisition and Recycling Framework.

Closed-loop system is crucial as, waste materials are collected, processed, and recycled into new products, adopting an ongoing cycle of material usage. This holistic approach enhances resource efficiency by reducing dependence on virgin materials and minimizing waste generation. Adopting a closed-loop system enables companies to adhere to environmental regulations and achieve sustainability objectives. Governments should establish consumption and recycling zones to facilitate acquisition and cross-domain CDWM, encouraging collaboration and technology exchange. Accurate C&D waste assessments and a comprehensive cycle for generation, sorting, transportation, recycling, and promotion are crucial for sustainable waste management. Improved collaboration between CDWREs and the government can enhance recycling frameworks and promote industry standards [10].

5.2 R2- Strengthening Technological Innovation.

Engaging with research institutions supports CDWREs in technology and development, easing market expansion challenges. Advances in waste processing and tracking technologies are vital for effective waste management. Promoting Precast Construction Technologies minimizes pollution and facilitates material recovery without disruptive dismantling. Intensifying research on CDWM technologies and sustainable practices is crucial for efficient classification, sorting, and quality control, reducing

environmental impact [7]. Advanced technologies streamline operations, leading to decreased resource usage and enhanced efficiency. Through automation, optimization, and efficient resource allocation, these technologies frequently reduce manufacturing expenses. Strengthening technological innovation in the recycling industry, particularly within the framework of a circular economy, is crucial for enhancing efficiency, product quality, and overall sustainability.

5.3 R3- Expanding Product Types and Market.

Establishing a closed-loop recycling system for C&D waste can reduce intermediary profits and promote self-production and sales. Partnering with upstream and downstream industries enhances quality control and marketing strategies. CDWREs should leverage industry associations and expos to showcase products and improve visibility. Forming alliances with state-owned enterprises ensures a steady raw material supply and supports R&D, easing operational pressures [8]. CDWREs can develop contingency plans, establish alternative supply chains, and maintain financial reserves to ensure sufficient cash flow and capital to withstand market fluctuations and unexpected costs from events like natural disasters, market disruptions, and regulatory changes. Conducting comprehensive market analysis is crucial for effective implementation, as it aids in understanding current trends, consumer preferences, and potential demand for recycled products. Identifying market gaps where recycled materials can be introduced is also essential. Additionally, implementing mandatory consumer feedback mechanisms on recycled products helps better understand their needs and preferences, guiding product development and marketing strategies to strengthen recycled product enterprises. Advanced and efficient inventory management systems should be implemented to track and manage recycled products, preventing shortages and overproduction.

5.4 R4- Governmental Interventions.

Governmental interventions are crucial in providing regulatory frameworks which is the backbone of the enterprise as it helps to promote stability in markets, ensuring rational competition and protecting consumers from exploitation. Converting C&D waste into secondary resources is crucial for advancing a circular economy. Key factors include government support, efficient supply chains, and technology investments. In emerging economies, aligning environmental and economic goals is vital. Policymakers, practitioners, and the public must collaborate to improve incentives and support for CDWM enterprises. Effective economic incentives are needed to enhance the viability of the recycled products market [2]. Executing strict quality standards for recycled materials can help build consumer trust and ensure that recycled products meet industry requirements. Quality certification programs can validate the safety and performance of recycled materials. Governmental effective involvements can set standards for

C&D waste recycling, promoting effective waste management and environmental protection with focusing on circular economy. Government support can also boost market demand for recycled C&D products through policies like procurement mandates, tax incentives, and subsidies, thereby creating economic opportunities for recycling enterprises communities.

5.5 R5- Public Private Partnership.

Public-private participation (PPP) plays a fundamental role in advancing the circular economy within CDWREs. By combining the strengths of both sectors, PPPs can enhance resource efficiency, innovation, and market reach. Creating funding models that blend public and private investments can boost the financial viability of recycling projects. For instance, combining public grants with private loans can provide a solid financial foundation. Co-financing arrangements where both sectors share the costs and benefits can also make these projects more feasible and sustainable. This collaborative approach ensures that recycling initiatives have the necessary resources to succeed and grow. Establishing joint systems for monitoring and evaluating the performance of recycling initiatives can ensure continuous improvement. This can involve setting performance indicators, conducting regular assessments, and reporting on progress.

6. RESEARCH LIMITATIONS

The research concentrates solely on challenges, practices, and procedures specific to CDWREs in developing countries, potentially limiting its applicability to other regions or countries globally. Additionally, it may not encompass all essential stakeholders, including builders, waste management companies potentially leading to an incomplete understanding of construction waste management industry challenges.

7. CONCLUSIONS

CDWREs play a vital role in C&D waste management within the circular economy, necessitating immediate attention for devising long-term solutions in developing countries. This research's core objective was to investigate impediments hindering the growth of CDWREs in developing countries. Through exploring the perspectives of researchers and stakeholders, the study aimed to illuminate challenges in the recycling enterprise sector. The findings offer valuable insights for stakeholders seeking to enhance recycling enterprises in developing countries. Additionally, the research presents standards and recommendations to address identified issues and promote sustainable waste management aligned with circular economy principles and sustainability. CDWREs can emerge as key drivers of positive environmental, social, and economic impact, contributing significantly to the achievement of sustainable development goals on both local and global scales.

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