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The Development of Construction and Demolition Waste Management System in Enterprise

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Abstract

Construction and demolition waste accounts for a significant portion of global waste and requires effective management systems to mitigate its environmental and economic impacts. This study creates a structured construction and demolition waste management system that integrates management in the recycling of used building materials, development of safety systems, stakeholder engagement, public awareness, technology integration and economic factors that closely align staff development with company development to form relevant indicators. The study provides a comprehensive guiding framework with practical strategies for policy makers, construction companies and urban planners to improve the efficiency of waste management and promote the sustainable development of the construction and demolition waste materials industry.

Keywords: Construction and Demolition Waste, Sustainable Development, Staff Development

Introduction

Construction and demolition waste (CDW) constitutes a substantial proportion of global waste, contributing approximately 25–30% of the total waste generated worldwide (Cook et al., 2022). This stream, comprising materials such as concrete, asphalt, metals, wood, and gypsum, originates predominantly from construction, renovation, and demolition activities (Rampit et al., 2020). Managing CDW effectively is crucial for mitigating its environmental and socio-economic impacts. A Construction and Demolition Waste Management System (CDWMS) provides a structured framework to minimize, manage, and recycle CDW. These systems incorporate policies, advanced technologies, and operational strategies aligned with the principles of the waste hierarchy: reduce, reuse, and recycle. Key elements of a CDWMS include designing materials to facilitate deconstruction, employing durable materials, and adopting modular construction techniques to minimize waste. Additionally, advanced material sorting technologies, including optical scanners and AI-powered robots, enhance recycling efficiency. Policy measures such as mandatory recycling targets, landfill bans on recyclable materials, and tax incentives for the use of recycled materials further strengthen these systems. Despite advancements in recycling technologies and regulatory frameworks, challenges persist. Insufficient infrastructure for sorting and recycling CDW hampers progress in many regions. Public awareness of the benefits of recycling remains limited, resulting in improper waste disposal practices. Furthermore, recycling CDW often incurs higher costs than landfill disposal, particularly in developing nations. Addressing these challenges through robust CDW management systems is imperative for achieving sustainable construction practices globally. The research is critical to the promotion of sustainable management practices and circular economy principles to mitigate the environmental impacts of CDW. Guidance is provided to policy makers through the development of a systematic framework. By integrating waste management with the industry's sustainable development goals, guidance is provided through a systematic framework to improve the efficiency of recycling used building materials and ensure long-term environmental and economic sustainability.

Overview of Construction and Demolition Waste Evaluation System

CDW management plays a pivotal role in advancing sustainable urban development by mitigating environmental impacts and promoting resource efficiency. The effectiveness of CDW management systems is determined by evaluating diverse factors, such as waste generation, transportation logistics, resource utilization, disposal practices, policy frameworks, and stakeholder engagement (Ziyi et al., 2024).

A recent study introduces a comprehensive framework for evaluating the efficiency of CDW management at the municipal level, structured around three core dimensions. The first dimension, whole-process management, examines stages from waste generation to final disposal, with an emphasis on source control, transport logistics, resource utilization, and disposal practices. The second dimension, security system development, evaluates the establishment of supportive systems, encompassing market mechanisms, technological advancements, and regulatory frameworks. The third dimension focuses on stakeholder participation and access, assessing stakeholder engagement and satisfaction, acknowledging their pivotal role in successful waste management. The framework comprises 9 first-level indicators and 31 s-level indicators, offering a systematic approach to assess and enhance urban construction waste management (Chen et al., 2024).

Technological advancements have significantly improved the prediction and management of CDW (Awad et al., 2024). For instance, the integration of Building Information Modelling (BIM) with Machine Learning (ML) techniques enables precise waste quantification, particularly in demolition projects. Building Information Modelling (BIM) integrated with machine learning is a digital framework that enables the creation and management of a comprehensive representation of a facility's physical and functional attributes. Functioning as a centralized knowledge resource, BIM enhances decision-making across the entire building lifecycle, spanning initial design and construction through to operation and maintenance (Sacks et al., 2020). Recent advances involve integrating BIM with machine learning to predict the amount of recyclable and landfill material generated by building demolition. This integration provides detailed insights into the waste cycle, contributing to better planning and management. One study, using a dataset of 2,280 demolition projects, developed an ML model that achieved an R^2 value of 0.9977, reflecting exceptional predictive accuracy (Saka et al., 2024). This integration facilitates the forecasting of recyclable and landfill-bound materials, thereby enhancing project planning and advancing circular economy principles in construction. Effective C&D waste assessment systems are essential to minimize environmental impacts and improve resource efficiency. Life Cycle Assessment (LCA) provides a holistic framework for quantifying environmental impacts across all stages of a product's lifecycle, spanning raw material extraction, production, use, and final disposal (Moni et al., 2020). By evaluating material and energy flows at each phase, LCA offers critical insights into a product's ecological footprint, facilitating the development of more sustainable design and production practices. This method assesses the environmental impact of construction materials throughout their life cycle, from extraction to disposal. Implementing LCA can lead to more sustainable material choices and waste reduction strategies.

CDW management strategies vary across regions. The European Union prioritizes construction material recycling and adopts a cradle-to-grave approach to resource management. The 2016 EU Agreement on CDW Management emphasizes not only economic benefits but also job creation and landfill reduction. Landfill taxation has been particularly effective in reducing waste, with certain countries achieving recycling rates exceeding 70% (Gálvez-Martos et al., 2018). In contrast, the United States lacks a national landfill tax, but state and local governments impose varied fees. Programs such as California's CalRecycle offer guidelines and incentives to encourage waste diversion, recycling, and reuse of materials. The U.S. Environmental Protection Agency (EPA) has also developed the Sustainable Materials Management (SMM) program to address the escalating C&D waste issue (Jin & Chen, 2019).

Challenges to effective C&D waste management persist. Accurate waste quantification is critical for effective resource allocation, yet inconsistencies in data remain. The development and enforcement of regulatory frameworks that incentivize recycling and proper disposal practices are crucial, as is ensuring active participation from all stakeholders in construction projects. Addressing these challenges requires a multifaceted approach that integrates robust evaluation frameworks, technological innovations, supportive policy measures, and stakeholder engagement to enhance the sustainability and efficiency of C&D waste management systems (Ma et al., 2020).

Significance of the CDW Management Evaluation System

The significance of assessing CDW management systems lies in their ability to enhance urban sustainability, resource efficiency, and environmental protection. A robust assessment framework allows cities to identify strengths and weaknesses in their waste management practices, thereby enabling targeted improvements and informed policy development. An effective assessment system mitigates the environmental impact of CDW by promoting recycling and appropriate disposal methods, thus minimizing pollution, and conserving natural resources (Elshaboury et al., 2022). Evaluating management efficiency encourages optimal resource use, reduces dependence on raw materials, and supports circular economy principles.

A comprehensive framework informs policymakers about the effectiveness of existing waste management strategies, guiding the formulation of regulations that foster sustainable practices (Chen et al., 2024). The integration of technologies such as Building Information Modelling (BIM) and Machine Learning (ML) into assessment systems enhances predictive accuracy, enabling precise waste quantification and improved planning (Saka et al., 2024).

Moreover, assessment systems that measure stakeholder engagement and satisfaction acknowledge the essential roles of all parties involved, fostering collaboration and commitment to effective waste management.

Efficient waste management assessments can yield significant economic benefits, including cost savings from reduced material consumption and disposal expenses, while also creating job opportunities in the recycling and waste management sectors (Purchase et al., 2021).

In summary, the significance of C&D waste management assessment systems spans environmental, economic, and social dimensions. These systems are critical tools for cities seeking to strengthen waste management practices, achieve sustainable development goals, and advance circular economy objectives.

Establishment of CDW Management Evaluation System

Establishing a comprehensive assessment system for CDW management is essential for enhancing the sustainability and resource efficiency of urban development. Key indicators identified in relevant studies include:

(a) Whole-process management: Source control measures aimed at minimizing waste generation during project planning and design; assessment of the efficiency and environmental impact of waste transport logistics; resource recovery through the recycling and reuse of materials wherever possible; and the safe and sustainable disposal of non-recyclable C&D waste. These indicators evaluate the effectiveness of C&D waste management from generation to final disposal.

(b) Safety system development: The availability and robustness of markets for recycled C&D materials, adoption of technologies that improve waste processing and recycling efficiency, and the establishment and enforcement of policies that support sustainable waste management. These indicators reflect the strength of the infrastructure underpinning effective C&D waste management.

(c) Stakeholder participation and satisfaction: The extent of involvement by stakeholders—including contractors, policymakers, and communities—in waste management processes, as well as their satisfaction with current practices and outcomes. Assessing these indicators provides insights into collaborative efforts and stakeholder engagement in waste management.

(d) Technological integration: The use of Building Information Modeling (BIM) for precise waste quantification and management, along with machine learning (ML) models to predict waste generation and optimize recycling processes. The integration of these technologies enhances predictive accuracy and planning efficiency.

(e) Economic indicators: Cost savings achieved through efficient material use and waste disposal, alongside job creation in the recycling and waste management sectors. These indicators capture the economic advantages of effective C&D waste management.

The implementation of an assessment system incorporating these indicators enables cities to identify areas for improvement, formulate targeted policies, and promote sustainable practices in C&D waste management.

The Indicators of the Construction and Demolition Waste Management System

(a) Main aspects of waste management system of documentary study

Whole process management, safe system development, stakeholder involvement and satisfaction, technology integration, and economics should all be considered. Table 1 illustrates the five main aspects of waste management system indicators.

Table 1

Main indicators of waste management system (Ramos & Martinho, 2021; Ganjbakhsh, 2016; Campos et al., 2012; Mahakud et al., 2021; Bombiak & Marciniuk-Kluska, 2018).

Indicators	Description of indicators
A	Construction and demolition waste management of staff knowledge and awareness for construction enterprises
B	Construction and demolition waste management of staff skills development for construction enterprises
C	Construction and demolition waste management of staff practical application for construction enterprises
D	Construction and demolition waste management of staff behavioral change for construction enterprises
E	Sustainable management for construction enterprises

Main aspects of waste management system include the enhancement of employee knowledge and awareness, improvement of practical skills, application of theoretical knowledge, development of positive work behaviors, and sustainable management practices (Kang et al., 2022). These elements form the foundation of workforce development and align with industry needs.

(b) Selecting and integrating criteria using the Delphi method

The Delphi method, a systematic approach for achieving expert consensus through iterative surveys and structured feedback, is widely employed in forecasting, decision-making, and policy analysis (Fish & Busby, 1996). In this study, the Delphi method was used, and the key indicators were further refined by expert guidance. Table 2 shows the preliminary indicator and sub-indicator of the waste management system.

Table 2
Preliminary indicator and sub-indicator

Indicator (preliminary)	Sub-indicator (preliminary)
C&D waste management of staff knowledge and awareness for construction enterprises	Accurately identify and segregate C&D wastes
	Knowledge of national and local laws and regulations on C&D waste management
	Awareness of the need to reduce the generation of C&D wastes
	Compliance with safety procedures for C&D waste disposal
	Active participation in corporate C&D waste management processes
	Proactive learning of new C&D waste management technologies and policies
C&D waste management of staff skills development for construction enterprises	Skills in using digital management tools
	Safe disposal of hazardous waste and emergency response skills
	Capacity to operate waste minimization and treatment technologies
	Precision sorting and picking skills for C&D waste
	Waste resource utilization technology application capacity
C&D waste management of staff practical application for construction enterprises	On-site waste storage specifications
	Application of minimization techniques in demolition operations
	Waste removal compliance checks
	On-site resource utilization of wastes
	Emergency response and pollution prevention and control
C&D waste management of staff behavioral change for construction enterprises	Implementation of separate drop-off of C&D wastes
	Regulating the transport and disposal of C&D wastes
	Behavioral monitoring and feedback
	Promoting behaviors that reduce the generation of C&D wastes
	Organization of awareness-raising and educational seminars
Sustainable management for construction enterprises	All types of related resource management
	Environmental management
	Quality management
	Assumption of social responsibility
	Innovation and development management

Research Contribution
This study contributes to the management of construction and demolition waste building materials through a systematic and comprehensive assessment of structured indicators for waste building materials systems. The indicators in this study emphasize the integration of the development of the company with the employees themselves. The indicators are developed by combining the knowledge, awareness, skills, behaviors and practices of the employees and the sustainable development of the company. To provide the appropriate direction for the development of the enterprise. The indicators will also consider technology, circular economy principles, laws, and other relevant factors to make the indicators more comprehensive. This study has practical implications for companies, as it provides structured

guidelines to enhance the practice of construction and demolition waste management, which can support the sustainable development of the construction industry.

Conclusion

This research examines a structured C&D waste management system that can mitigate environmental impacts and promote the development of sustainable practices in the construction industry. It provides a scientifically valid approach to improving waste management by developing an integrated assessment framework combining various indicators. This article can provide policy makers, construction companies and urban planning managers of construction and demolition waste management with practical strategies to enhance waste management practices and achieve long-term sustainability in the industry.

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