




ENVIRONMENTAL IMPACTS OF DIFFUSE LOGISTICS IN URBAN CONSTRUCTION AND DEMOLITION DEBRIS MANAGEMENT

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ABSTRACT

Urban construction and demolition (C&D) activities generate large volumes of debris that, when managed through fragmented and poorly coordinated logistics systems, produce significant environmental impacts. Diffuse logistics characterized by decentralized waste generation, informal transport, and irregular disposal pathways intensify greenhouse gas emissions, promote illegal dumping, and undermine material recovery and circular economy objectives. This article examines the environmental consequences associated with diffuse C&D waste logistics in urban contexts and discusses strategies through which cities can mitigate these negative effects. Drawing on academic literature and institutional reports, the analysis highlights the roles of regulatory frameworks, economic incentives, infrastructure investment, and social inclusion in improving environmental performance. The findings suggest that transforming diffuse waste flows into structured material management systems can substantially reduce emissions, conserve natural resources, and support sustainable urban development.

Keywords: Construction and Demolition Waste. Diffuse Logistics. Urban Waste Management. Environmental Impact. Circular Economy.



1 INTRODUCTION

Urban areas generate substantial volumes of construction and demolition (C&D) debris as a direct consequence of population growth, infrastructure expansion, and continuous processes of urban renewal. When the collection, transport, and disposal of this material occur through a fragmented and poorly coordinated system often referred to as diffuse logistics the environmental impacts are significantly intensified. Diffuse logistics are characterized by numerous small-scale waste generators, informal or unregulated transport operators, irregular collection schedules, and the proliferation of unauthorized disposal sites. Together, these factors contribute to increased greenhouse gas emissions, land degradation, resource inefficiency, and heightened public health risks. Studies on urban waste systems consistently indicate that unmanaged or weakly regulated C&D waste flows exacerbate environmental pressures compared to centralized and planned logistics structures (Ramos et al., 2023; EPA, 2025).

From a climate and air-quality perspective, diffuse logistics lead to inefficient transportation patterns, including low load factors, redundant routes, and extended travel distances between generation and disposal points. These inefficiencies result in higher fuel consumption and carbon dioxide emissions per unit of material transported when compared to consolidated collection systems. In addition, the lack of standardized containment during transport often causes the dispersion of dust and fine particulate matter, negatively affecting air quality in densely populated urban areas. Research demonstrates that such emissions disproportionately impact vulnerable communities located near informal disposal sites or along heavily trafficked waste transport corridors (Yu et al., 2021; Lee et al., 2024).

Another critical environmental consequence of diffuse C&D waste logistics is the increased incidence of illegal dumping. Construction debris is frequently deposited in vacant lots, riverbanks, wetlands, and road margins, where it alters natural drainage systems, accelerates soil erosion, and increases flood risk. These informal disposal practices also degrade urban landscapes and impose long-term remediation costs on municipalities. Empirical evidence from multiple cities shows that the environmental damage associated with cleaning up illegal dumping sites often exceeds the cost of implementing structured collection and recycling systems in the first place (Foster et al., 2025).



Diffuse logistics also undermine the principles of the circular economy by preventing effective material recovery. When debris streams are mixed, contaminated, or disposed of without prior sorting, the technical and economic feasibility of reuse and recycling is severely reduced. This results in the loss of potentially valuable secondary materials such as aggregates, metals, and wood, increasing dependence on virgin raw materials and the associated environmental impacts of extraction and processing. Life cycle assessment studies indicate that recycling and reuse of C&D materials can significantly reduce energy use, greenhouse gas emissions, and land occupation when compared to landfilling or uncontrolled disposal (Ramos et al., 2023; Yu et al., 2021).

Cities seeking to mitigate the environmental impacts of diffuse logistics must adopt integrated policy and operational strategies. Regulatory frameworks that clearly define C&D waste responsibilities, require source separation, and enforce controlled transport and disposal pathways are essential. Economic instruments, including disposal fees that reflect environmental externalities and incentives for the use of recycled materials in public procurement, have proven effective in altering behavior across the construction sector. Evidence from European and North American contexts shows that public demand for recycled aggregates in infrastructure projects plays a decisive role in stabilizing secondary materials markets and reducing illegal dumping (Foster et al., 2025; EPA, 2025).

Operational improvements are equally important. The establishment of strategically located transfer stations, neighborhood-scale drop-off points, and mobile recycling units can reduce transport distances and discourage informal disposal. When combined with route optimization and licensed hauling systems, these measures substantially lower fuel consumption and emissions associated with debris transport. Studies comparing centralized and decentralized processing models suggest that hybrid systems—local consolidation with standardized quality control offer the best environmental and economic performance in large metropolitan areas (Lee et al., 2024).

Social and governance dimensions further influence the success of interventions. In many cities, informal workers play a significant role in collecting and processing construction debris. Excluding these actors can perpetuate illegal practices, whereas inclusive policies that formalize their activities, provide training, and integrate them into regulated supply chains can improve environmental outcomes while generating social benefits. Public awareness campaigns targeting small contractors and households



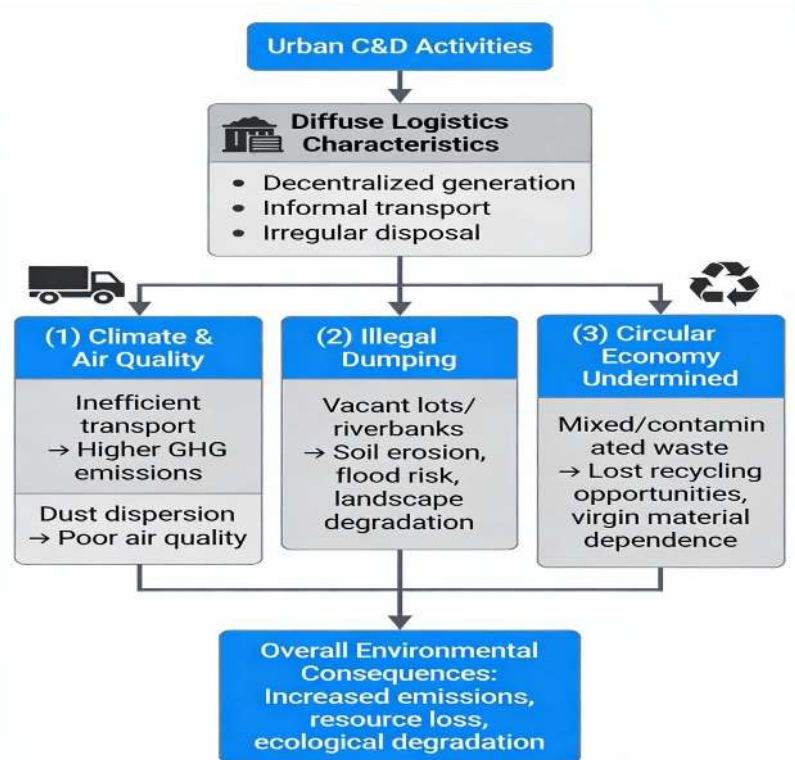
involved in renovations also contribute to better compliance with sorting and disposal requirements (Yu et al., 2021).

Monitoring and evaluation tools are critical for managing diffuse logistics systems. Material flow analysis and life cycle assessment enable municipalities to identify environmental hotspots, compare management scenarios, and prioritize investments. Standardized indicators such as diversion rates, vehicle-kilometers traveled, and recycled material uptake support evidence-based decision-making and policy transparency. Recent academic reviews emphasize the need for consistent, city-level data to accurately assess the performance of C&D waste management strategies and their environmental impacts (Ramos et al., 2023).

The flowchart illustrates the environmental impacts stemming from diffuse logistics in urban construction and demolition (C&D) waste management, beginning with urban C&D activities that generate debris through decentralized sources. This leads to key characteristics of diffuse logistics such as informal transport, irregular collection schedules, and unauthorized disposal which branch into three primary consequence pathways: climate and air quality degradation via inefficient transport routes causing higher GHG emissions and dust dispersion; illegal dumping in sensitive areas like riverbanks and vacant lots, resulting in soil erosion, flood risks, and landscape damage; and undermining of circular economy principles through mixed, contaminated waste streams that prevent material recovery and increase reliance on virgin resources. These impacts converge at the bottom into overall environmental consequences, including elevated emissions, resource loss, and ecological degradation, emphasizing the need for structured logistics to mitigate such effects.

Figure 1

Flowchart of Environmental Impacts from Diffuse Logistics in Urban C&D Waste Management



Source: Created by author.

In conclusion, the diffuse logistics of urban construction and demolition debris amplify environmental impacts through inefficient transportation, illegal dumping, resource loss, and local ecological degradation. Addressing these challenges requires coordinated regulatory frameworks, economic incentives, infrastructure investment, and social inclusion strategies. By transforming C&D debris from a dispersed waste problem into a managed urban material flow, cities can significantly reduce emissions, conserve natural resources, and advance more sustainable and resilient urban development pathways.



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