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RESEARCH ARTICLE

Economic Benefit of Construction Waste Management with Social Cost for Neighbourhood Communities

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Abstract

Managing construction waste is crucial for environmental sustainability, particularly in large cities where it has become a major issue. The construction industry generates substantial waste, causing environmental impacts and public concern. This has led to pressure on the sector to reduce costs and improve environmental quality by adopting waste reduction measures, achievable through effective management and recycling. Reusing and recycling construction waste are essential for reducing costs and minimizing overall waste. Construction waste management affects society economically, socially, and environmentally. Economic tools are effective in encouraging eco-friendly practices, but the social impacts, such as disturbances to nearby residents, are less studied. This paper analyses the economic feasibility of minimizing construction waste materials, incorporating social costs for neighboring communities through a comprehensive cost-benefit analysis. The findings indicate that waste minimization with consideration for social costs is economically feasible and significantly contributes to improving both environmental and social performances.

Keywords: Construction waste management, Social Performance, Cost Benefit Analysis, Management measures, Social Cost.

Introduction

In order to ascertain the financial viability and societal value of construction and demolition waste management (CDWM), it is increasingly being assessed through economic lenses, specifically Cost-Benefit Analysis (CBA). Significant waste streams are produced by the construction industry, which results in both direct costs like transportation and landfill fees and indirect social costs like environmental deterioration and effects on public health (Ajayi et al., 2020). Due to the exclusion of externalities from financial accounting, traditional disposal-based systems frequently underestimate these wider economic burdens. A structured framework for weighing the financial costs of waste reduction, recycling infrastructure, and material recovery systems against the financial benefits of resource recovery, reduced disposal costs, and increased efficiency is provided by cost-benefit analysis (Lu & Yuan, 2010).

Research indicates that CDWM strategies frequently produce positive net present value when lifecycle savings and avoided penalties are taken into account, particularly in areas with landfill taxes and environmental regulations (Wang et al., 2022). However, conclusions drawn from economic analyses that ignore social costs are insufficient. According to Marzouk et al. (2014), social cost components such as noise pollution, traffic congestion, dust exposure, and health risks result in quantifiable welfare losses for nearby communities. By incorporating these externalities into CBA, policy decision-making is improved by aligning CDWM evaluation with welfare economics principles and the triple bottom line approach (Purchase et al., 2022). CDWM plays a vital role in sustainable construction by reducing environmental impact, optimizing resource use, and minimizing landfill dependency. However, existing approaches largely overlook the social dimension, necessitating integrated evaluation frameworks.

Literature Review

According to CDWM economic analyses, material recovery and waste minimization can lower project-level costs by avoiding landfill fees and increasing resource efficiency. In a similar vein, Lu and Yuan (2010) found crucial success factors

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that have a direct impact on construction waste systems' cost performance. Recent research highlights the increasing significance of circularity in the management of construction and demolition waste (CDW), especially in economies that are developing quickly. Frameworks for construction and demolition waste management are being created more frequently in an effort to lessen environmental impact and increase resource efficiency. In order to improve material recovery and reuse rates, Bao and Lu suggest circular economy strategies and draw attention to the structural waste handling inefficiencies that fast-emerging economies face (Bao et al., 2020).

To elaborate, Kabirifar et al. highlight the crucial role of the 3R (reduce, reuse, recycle) principles in enhancing CDW management systems and identify important contributing factors like regulatory gaps, a lack of stakeholder coordination, and inadequate awareness (Kabirifar et al., 2020). Tafesse et al. examine the socioeconomic and environmental effects of construction waste from a wider angle, showing that inadequate waste management techniques not only deteriorate environmental quality but also cause financial losses and social difficulties, especially in developing nations (Tafesse et al., 2022).

In order to aid in decision-making, construction and demolition waste (CDW) management is increasingly incorporating technological and economic evaluation techniques. Recent studies highlight the significance of cost-benefit analysis (CBA) in assessing waste management strategies throughout the whole waste chain, rather than concentrating only on design-stage interventions. In order to show that efficient CDW management can produce long-term net economic benefits despite higher initial costs, Yuan et al. created a system dynamics-based CBA model that captures the interactions between waste generation, recycling, and disposal processes (Yuan et al., 2011). Additionally, their findings demonstrate how policy tools like landfill fees have a substantial impact on economic results as well as unintended social costs like illegal dumping and environmental externalities.

Similar to this, Ding et al. evaluate demolition waste management using an agent-based modeling approach, demonstrating that effective tactics like selective demolition can lower overall costs while enhancing social and environmental outcomes (Ding et al., 2022). Together, these studies show that creating a sustainable and workable CDW management framework requires taking social cost and economic efficiency into account. By lowering environmental effects and increasing resource efficiency, construction and demolition waste management (CDWM) significantly contributes to sustainability. Recent research emphasizes the value of circular economy, recycling, and reuse strategies in reducing waste production and reliance on landfills. However, the majority of current research concentrates on environmental and economic factors, paying little attention to social effects, suggesting the need for more thorough evaluation frameworks (Zhang et al., 2023; Papamichael et al., 2023; Mukherjee et al., 2023).

Description of the Model

A key element of sustainable construction is CDWM, which emphasizes waste reduction, reuse, recycling, and safe disposal to reduce environmental impact and landfill dependency. In addition to conserving natural resources and lowering air, water, and soil pollution, effective CDWM techniques also improve resource efficiency and reduce disposal costs. In addition to reducing energy consumption and the need for raw material extraction, recycling and waste reduction also help to mitigate climate change. CDWM has significant social ramifications, such as public health, community well-being, and job creation, in addition to its positive effects on the environment and the economy. However, because social performance is difficult to measure and is not given as much priority in practice, the majority of current research focuses on economic and environmental factors. Contractors are encouraged to adopt sustainable practices that strike a balance between economic viability and environmental and social responsibility by incorporating social costs into decision-making frameworks like Cost-Effectiveness Analysis (CEA), which allows for a more thorough evaluation of waste management strategies.

Model Formulation

The study introduces a model focused on the economic advantages of managing construction waste while considering the social costs incurred by neighbourhood communities. It evaluates the overall cost-benefit of CDWM, taking into account both the total cost of CDWM and the social costs associated with residential building activities in urban areas. The analysis involves measuring the impact on third parties' assets by observing their responses to restore their asset standards to the original state. A Cost-Effectiveness Analysis (CEA) framework incorporating social costs alongside economic factors to evaluate CDWM strategies. The model enables a more comprehensive assessment of waste management alternatives by capturing environmental, economic, and social impacts.

4.1 CALCULATION OF TOTAL BENEFIT FROM CDWM

The aggregate benefits resulting from the reuse and recycling of construction waste materials encompass all the advantages, including direct, indirect, and intangible benefits. The following equation provides an expression for the total benefits.

$$TB_{MW} = D_{CS} + P_{CS} + R_{SW} + T_{CS}$$

where, TB_{MW} represents the overall benefits derived from the reuse and recycling of construction waste materials on the site, P_{CS} denotes the cost savings achieved through the purchase of reused and recycled materials, R_{SW} stands for the revenue generated from the sale of scrap construction waste materials, T_{CS} represents the savings in waste collection and transportation costs, and D_{CS} reflects the cost savings resulting from avoiding landfill charges through reuse and recycling.

For the calculation of above mentioned costs we have,

Savings in disposal costs (D_{CS}) = Unit landfill charge (L_{UC}) × Total saved waste materials (TM_{WS})

Savings in purchase costs (P_{CS})= Total saved waste materials (TM_{WS}) × Unit cost of material purchasing (P_{UC})

Revenue generated from selling wasted materials (R_{SW}) = Total saved waste materials (TM_{WS}) × Unit price of new materials (NM_{UC})

Savings in transportation costs (T_{CS}) = Unit transportation cost (T_{UC}) × Total saved waste materials (TM_{WS})

The immediate advantages of reusing and recycling include cost savings through the reuse and recycling of construction waste materials, as well as revenue generated from selling scrap materials. Indirect benefits encompass savings in waste collection and transportation costs, along with reduced expenses related to landfill charges due to the reuse and recycling of construction waste materials. Cost savings in purchasing highlight that the company achieved financial benefits by reusing and recycling waste materials instead of procuring new ones. Without the option to reuse and recycle, the company would have incurred additional costs in procuring these materials.

Calculation of Total Cost of CDWM

The cumulative costs related to the reusing and recycling of construction waste materials encompass all incremental expenses, including direct, indirect, and intangible costs. This summation is expressed by the equation

$$TC_{MW} = C_C + D_C + RC_C + RU_C + S_C + T_C + E_C$$

In the context of reusing and recycling construction waste materials on the site, encompasses various cost components. It includes collecting expenses (C_C), Disposal costs (D_C), Recycling expenditures (RC_C), Reusing costs (RU_C), Sorting expenses (S_C), Transportation costs (T_C) and Environmental expenses (E_C).

To compute the costs mentioned above, we have the following:

Collection cost (C_C) = Unit collecting cost (C_U) × Collected waste (C_W)

Disposal cost (D_C)= Waste disposed (D_W) × Unit landfill charge (L_{UC})

Recycling cost (RC_C) = Unit recycling cost (RC_{UC})× Waste recycled (RC_W)

Reusing cost (RU_C) = Unit cost of reusing (RU_{UC}) × Reused waste (RU_W)

Sorting cost (S_C) = Sorted waste (S_W)× Unit sorting cost (S_{UC})

Transportation cost (T_C)= Unit transportation cost (T_{UC}) × Waste disposed (D_W)

Environmental cost (E_C) = Illegally dumped waste (ID_W) × Unit cost of illegal dumping (ID_{UC})Top of FormTop of Form

Calculation of Social Cost

The process of quantifying social costs comprises six phases. The phases involved are listed as follows.

Identifying the Types of Impacts

In the initial phase, the focus lies on identifying the various types of impacts associated with social costs. The social costs have been classified into distinct categories based on their impacts, encompassing traffic-related costs, economic activity-related costs, pollution impacts, and ecological, social, and health-related impacts.

Recognizing Components Contributing to Social Costs

In the second phase, the focus shifts to identifying the individual components that make up the various social costs identified in the earlier phase. The assessment of impact types of social costs is conducted concerning the components owned by the community. The measurement of life quality involves evaluating diverse determinants, encompassing physical well-being, psychological well-being, and a sense of physical belonging.

Specifically, the concept of physical belonging is intertwined with connections to the physical environments of one's home, workplace, neighbourhood (Ngbhd), school, and community. The third parties, recognized as possessed assets, namely households, houses, and Ngbhd, are identified as components contributing to social costs. The social cost equation presented below encompasses local residents and accounts for the components identified in Phase 2.

In the first equation, SC_{LOR} signifies the social cost incurred by local residents, SC_{NH} represents the social cost associated with the Ngbhd, SC_{HS} stands for the social cost attributed to households, and SC_{CH} denotes the social cost linked to cars or houses.

$$SC_{LOR} = SC_{NH} + SC_{HS} + SC_{CH}$$

Recognition of Sub-components within Social Costs

During the third phase, the emphasis lies in pinpointing the sub-components that constitute the larger category of social costs previously identified. During this stage, the subcomponents of each social cost component are discerned by separating the various elements of social cost. Additionally, an equation is put forth to compute each individual social cost component.

Components within the Neighbourhood

Four subcomponents are suggested for the Ngbhd, identified as the expense associated with issues related to traffic flow and congestion. (C_{TP}), The financial burden associated with issues or challenges related to car parking space (C C_{CP}), The expense incurred due to inadequacies in utilizing recreational facilities within the Ngbhd. (C_{RF}), and the expenditure linked to modifications in the overall environmental quality or standard of the Ngbhd. (C_{AS}). Equation introduced to compute the social cost of the Ngbhd by incorporating these subcomponents is

$$SC_{NH} = C_{TP} + C_{CP} + C_{RF} + C_{AS}$$

Components within Households

Three subcomponents for households are suggested, identified as the financial implications arising from difficulties in meeting daily necessities (C_{MN}), the expenses associated with preserving a standard level of health and personal care (C_{HC}) and the financial consequences arising from limitations in the ability to use outdoor spaces (C_{OS}). Utilizing these subcomponents, Equation 3 is employed to calculate the social cost associated with households.

$$SC_{HS} = C_{MN} + C_{HC} + C_{OS}$$

Components within the realm of housing and automobile

The subcomponents pertaining to houses and cars are identified as The financial impact attributed to the increased level of dirtiness in the outdoor areas of the house (C_{DO}), the financial consequences linked to the increased level of dirtiness in the indoor areas of the house (C_{DI}) and the financial implications resulting from the heightened level of dirtiness in the cars (C_{DC}). The expenses associated with upholding the standards of both houses and cars can be calculated using these components. Thus, the equation is employed to calculate the social cost of maintaining the standard of houses and cars,

$$SC_{CH} = C_{DO} + C_{DI} + C_{DC}$$

Recognizing the criteria contributing to the perceived nuisance.Top of Form

A field survey has to be conducted to identify the perceived nuisances experienced by residents in proximity to a construction site. Survey participants were chosen based on their residence within a 150-meter radius of a building construction site, as it has been demonstrated that the formation of additional construction dust significantly disturbs residents within this proximity. Following this, the pre-identified social cost components are employed to classify these specified nuisance criteria, with each criterion being linked to the aforementioned social cost sub-components.

Integration of results for Social Cost

Thus, the final equation for estimating the social cost by integrating above given equations is presented below as

$$SC_{LOR} = SC_{NH} + SC_{HS} + SC_{CH}$$

Calculation of Social Cost

The incurred social costs are assessed using five distinct empirical equations, detailed as follows: In the equation, the terms employed R_P represents the percentage of residents who have modified their daily routines. The addition of 1/60 to the equation serves to convert the time required from minutes to hours for each criterion. The inclusion of 1/30 in the equation is necessary because the reported number of additional cleanings is on a monthly basis, hence this value is added to convert it to a daily basis. The value 1/1000 is employed as a conversion factor for kilometres to metres.

The equation is formulated to aid in estimating the cost associated with increased dirtiness of a house/car, and it is expressed as follows:

$$C_{CAD} = W_{CL} \times T_{CL} \times N_{AC} \times R_P \times \frac{1}{60} \times \frac{1}{30}$$

In this context, C_{CAD} represents the daily cost incurred for cleaning up the additional dirt, W_{CL} stands for the hourly wage of the cleaner, T_{CL} is the duration needed for cleaning, expressed in minutes, is acquired from responses gathered in the questionnaire survey, N_{AC} is the count of additional cleaning sessions conducted in a month is also obtained from the questionnaire survey. C_{DO}, C_{DI} are calculated using this equation.

This equation is employed to aid in estimating C_{DC} , and it is expressed as follows:

$$C_{DC} = P_{CW} \times N_C \times N_{ACW} \times R_P \times \frac{1}{30}$$

where P_{CW} signifies the price of a car wash, N_{ACW} is the count of additional car washes, N_C represents the number of cars owned per each household.

This equation is utilized to aid in estimating the cost of additional distance travel, and it is expressed as follows:

$$C_{ADT} = D_{ADT} \times A_{PC} \times AP_F \times N_{ADT} \times R_P \times \frac{1}{1000}$$

where, C_{ADT} represents the daily expense associated with extra distance travelled, D_{ADT} denotes extra distance covered in a day, N_{ADT} signifies the frequency of the activity being repeated, A_{PC} denotes the car's average petroleum consumption per kilometer, AP_F stands for the average fuel price. $C_{TP}, C_{CP}, C_{RF}, C_{AS}, C_{MN}$ are calculated using this equation.

This equation is formulated to aid in estimating the cost associated with alterations in well-being, standard health, and personal care.

$$C_{HC} = AP_{VD} \times N_{AVD} \times R_P \times \frac{1}{30}$$

where, AP_{VD} denotes the average expense for consulting a doctor, N_{AVD} is the extra count of visits to a doctor.

In this research, it is assumed that the calculation of C_{OS} can be derived from the daily expenses associated with increased use of air conditioning. This is due to the necessity for residents to spend more time indoors and use air conditioning to regulate room temperature.

$$C_{OS} = A_{EC} \times E_C \times U_{AAC} \times R_P$$

where, A_{EC} is the mean electricity usage of AC per hour, E_C is cost of electricity per kilowatt-hour, U_{AAC} is the extra hours of air-conditioning usage per day.

Cost Effectiveness Analysis (CEA)

The study calculated the net benefits to assess the economic viability of reusing and recycling construction waste materials at the project site. The net benefit is determined by Equation given below, representing the subtraction of total costs from total benefits.

$$CEA = TB_{MW} - TC_{MW} - SC_{LOR}$$

where, CEA represents the Cost Effectiveness Analysis, TB_{MW} is the Total Benefits of managing waste by reusing and recycling construction waste materials, and TC_{MW} stands for the total costs associated with the entire process of managing waste, SC_{LOR} represents social cost for local residents.

Cost Effectiveness Analysis = Total Benefits of managing waste - Total cost of managing waste - Social cost for local residents

= Disposal cost saving + Purchase cost saving + Revenue from selling wasted materials + Transportation cost saving − Cost of collecting − Cost of disposal − Cost of recycling − Cost of reusing − Cost of sorting − Cost of transportation − Environmental cost − Social cost for Ngbhd − Social cost for households − Social cost for house/cars

CEA

$$= D_{CS} + P_{CS} + R_{SW} + T_{CS} - C_C - D_C - RC_C - RU_C - S_C - T_C - E_C$$

$$- SC_{NH} - SC_{HH} - SC_{HC}$$

$$= (L_{UC} \times TM_{WS}) + (TM_{WS} \times P_{UC}) + (TM_{WS} \times NM_{UC}) + (T_{UC} \times TM_{WS})$$

$$-(C_C \times C_W) - (D_W \times L_{UC}) - (RC_{UC} \times RC_W) - (RU_{UC} \times RU_W)$$

$$-(S_W \times S_{UC}) - (T_{UC} \times D_W) - (ID_W \times ID_{UC})$$

$$-(C_{TP} + C_{CP} + C_{RF} + C_{AS}) - (C_{MN} + C_{HC} + C_{LO}) - (C_{DO} + C_{DI} + C_{DC})$$

Numerical Illustration

The information for the numerical illustration is provided as follows: Disposal cost saving (D_{CS}) = Rs. 839817, Purchase cost saving (P_{CS}) = Rs. 15977858, Revenue from selling wasted materials (R_{SW}) = Rs. 459000, Transportation cost saving (T_{CS}) = Rs. 671849, Cost of collecting and sorting ($C_C + S_C$) = Rs. 3149318, Cost of reusing and recycling ($RU_C + RC_C$) = Rs. 229500, Cost of disposal (D_C) = Rs. 124740, Cost of transportation (T_C) = Rs. 51120, Environmental cost (E_C) = Rs. 122760, Social cost for Ngbhd (SC_{NH}) = Rs. 448.47, Social cost for households (SC_{HH}) = Rs. 561.33, Social cost for house/car(s) (SC_{HC}) = Rs. 846.45

Calculation of Total Benefit from CDWM

$$TB_{MW} = D_{CS} + P_{CS} + R_{SW} + T_{CS}$$

$$= 839817 + 15977858 + 459000 + 671849$$

$$= 17948524$$

Calculation of Total Cost of CDWM

$$TC_{MW} = C_C + D_C + RC_C + RU_C + S_C + T_C + E_C$$

$$= 3149318 + 229500 + 124740 + 51120 + 122760$$

$$= 3677438$$

Calculation of Social Cost

$$SC_{LOR} = SC_{NH} + SC_{HS} + SC_{CH}$$

$$= 448.47 + 561.33 + 846.45$$

$$= 1856.25$$

Cost Effectiveness Analysis (CEA)

$$CEA = TB_{MW} - TC_{MW} - SC_{LOR}$$

$$= D_{CS} + P_{CS} + R_{SW} + T_{CS} - C_C - D_C - RC_C - RU_C - S_C - T_C - E_C$$

$$- SC_{NH} - SC_{HH} - SC_{HC}$$

$$=17948524-3677438-1856.25$$
$$=14269229.8$$

Result

The CEA's findings show that CDWM implementation has significant net benefits. The total benefit which includes revenue from salvaged waste, transportation cost savings, purchase cost savings, and disposal cost savings, was determined to be 17,948,524. On the other hand, 3,677,438 was the total cost, which included collection, disposal, recycling, reuse, storage, transportation, and environmental expenses. Furthermore, an estimated 1,856.25 was the total social cost, which included effects on health, noise, and community disruption. The net CEA value was determined to be 14,269,229.8 after taking into consideration all economic and social factors, indicating a notably favorable result. This finding shows that, even when social costs are explicitly taken into account, efficient CDWM practices are both economically and environmentally advantageous.

Discussion

According to the reviewed literature, CDWM produces favorable economic results when assessed using thorough cost-benefit frameworks that take into account the advantages of regulatory compliance, reduced disposal costs, and increased resource efficiency. However, internalizing social costs greatly increases the economic benefit. Underinvestment in sustainable waste systems results from ignoring externalities, whereas the economic case for waste minimization strategies is strengthened when health, environmental, and community impacts are monetized (Boardman et al., 2018; Marzouk et al., 2014).

Waste management is therefore changed from a compliance-driven activity into an economic strategy that improves welfare by incorporating social cost valuation into CDWM CBA models. Expanded CBA frameworks can be used by policymakers and construction companies to optimize resource allocation, support infrastructure investment decisions, and match construction methods with sustainable development goals. Therefore, when externalities are methodically taken into account, the economic benefit of CDWM extends beyond private savings to improve societal welfare.

The study's findings are in line with those of Kamma et al., (2025), who stated that waste reduction has the greatest positive effects on the economy and environment. In contrast to their methodology, the current study offers a more thorough assessment by including social costs in the analysis. Similar to how Atta et al., (2023) highlighted the environmental viability of recycling construction waste, this study expands the evaluation by incorporating social and economic aspects using a CEA framework.

Conclusion

- While CDWM offers financial advantages, it may also have negative social effects like traffic, noise, and environmental disruptions.
- Strict regulatory control is necessary because high landfill fees may encourage illegal dumping.
- For waste management to be responsible and balanced, social impacts must be taken into consideration.
- Making decisions that are more thorough and long-lasting is made possible by incorporating social costs into CEA.Economic instruments for minimizing CDW play an important role for encouraging contractors to embrace environmentally friendly construction practices.

Therefore, the conduct of cost–benefit analysis of construction and demolition waste management has attracted increasing research effort around the globe. There is a net benefit, even with the inclusion of social costs in our evaluation.

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