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ASSESSMENT OF SOLID WASTE GENERATION AND COST BENEFIT ANALYSIS OF OPERATING SOLID WASTE MANAGEMENT IN MADHYABINDU MUNICIPALITY, NEPAL

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ABSTRACT

This study conducts a cost-benefit analysis (CBA) of the integrated solid waste management (SWM) system in Madhyabindu Municipality, Nawalparasi (East), focusing on both financial sustainability and operational efficiency. Data were collected from household and institutional surveys, waste measurements, and municipal records, and were compared against Asian Development Bank (ADB) benchmarks. Household waste generation exceeded benchmarks (0.277–0.428 kg/unit/day vs. ADB's 0.16 kg), indicating inadequate segregation and reduction practices. In contrast, commercial and institutional sectors showed more efficient practices. Offices and hotels revealed inconsistencies, possibly due to change in behavior of waste generation. The three-month theoretical model projected revenue of NPR 2,356,243.82 against costs of NPR 2,409,623.08, with a Benefit-Cost Ratio (BCR) of 0.978 suggesting near sustainability if optimized. However, actual revenue (NPR 922,820) fell short of actual costs (NPR 2,255,046.03), yielding a much lower BCR of 0.409. Major expenditures were linked to recycling (26.50%), transportation (15.24%), and indirect administration (42.42%). No costs were incurred in landfilling due to reliance on pre-existing infrastructure. Revenue was mainly from user fees and compost sales; recyclable sales and fines contributed nothing despite being part of the model. The study concludes that while the system is theoretically sound, improvements in enforcement, source segregation, and recyclable marketing are essential for achieving practical financial viability and scalability.

***Keywords**: Solid Waste Management, Cost-Benefit Analysis, Waste Generation, Financial Sustainability, Nepal*

1. Introduction

Solid waste generation has become a growing concern in urbanizing municipalities of Nepal. Rapid urbanization, economic development, and changing consumption patterns have significantly increased the quantity and complexity of municipal waste. Poorly managed solid waste threatens

public health, water quality, and environmental aesthetics (Shuku, 2015).The Government of Nepal has delegated the responsibility of solid waste management to local municipalities under the Solid Waste Management Act, 2068. However, municipalities like Madhyabindu face challenges due to limited infrastructure, inadequate financing, and low community participation. Previous studies in Nepal have highlighted that rising household income and consumer behavior contribute significantly to waste volume (Asian Development Bank, 2013). International studies (Lohri, et al., 2014) support this by showing a positive correlation between income and per capita waste generation. Hence, understanding sector-specific waste generation and financial performance is essential for sustainable SWM planning.

This study aims to:

1. Assess Waste generation across sectors, their Composition and recyclability.
2. Examine revenue sources and assess financial performance.
3. Analyze cost drivers and determine the benefit-cost ratio.

2. Literature Review

Waste and Solid Waste

Waste refers to materials discarded as worthless, including solid, liquid, or semi-solid forms. Solid waste encompasses household garbage, industrial refuse, and other discarded materials harmful to the environment (Cointreau, 1982). In Nepal, the Environment Protection Act (2019) defines waste broadly to include liquids, gases, and solids disposed of in ways that degrade the environment.

Classification and Characteristics

Solid wastes originate from households, industries, agriculture, and construction, classified into hazardous and non-hazardous types (National Audit Office of Estonia). In Nepal, organic waste makes up the largest proportion of municipal solid waste, followed by plastics and paper (Asian Development Bank, 2013).

Importance of Waste Management

With growing populations and economic activities, effective waste management is critical to protect public health and the environment. Poor management leads to pollution, water contamination, flooding, and fire risks, negatively affecting urban life and tourism (Shuku, 2015).

Municipal Solid Waste Management (MSWM)

MSWM involves collection, transport, treatment, and disposal of waste generated from residential, commercial, and institutional sources (Zurbrugg, 2003). Municipalities in Nepal face challenges such as low collection efficiency, inadequate transportation, and lack of sanitary landfills (Asian Development Bank, 2013), (Khan, et al., 2022)

Waste Management Hierarchy

The preferred waste management approach prioritizes reduction, reuse, recycling, and composting to minimize landfill use and environmental impacts (USEPA). Composting organic waste reduces

landfill volume and provides cost-effective fertilizer, enhancing sustainability (FAO, n.d.), (Atalia, et al., 2015)

Resource Recovery and Recycling

Recycling and resource recovery not only reduce waste disposal costs but also generate employment and revenue, especially through informal sectors involved in recyclable collection (Mazumdar, 2012), (Khan, et al., 2022) Composting initiatives in Nepal remain limited, mostly practiced in rural areas, but show potential for urban adoption.

Collection, Transportation, and Disposal

Waste collection in Nepal varies from door-to-door to container-based systems, often with inefficiencies due to limited vehicles and infrastructure (Asian Development Bank, 2013) (Shuku, 2015). Disposal methods mostly rely on open dumping, with few municipalities operating sanitary landfills, raising environmental and health concerns (Asian Development Bank, 2013).

Stakeholders in Waste Management

Effective MSWM requires collaboration among local governments, private enterprises, NGOs, and communities. Nepal's private sector involvement is limited but critical for improving efficiency through partnerships and proper contract management (Asian Development Bank, 2013) (schubeler, et al., 1996).

Financial Aspects: Revenue and Costs

Sustainable waste management depends on adequate funding through user fees and municipal budgets. Fee collection is often inefficient, affecting service quality. Nepalese municipalities spend significant portions of their budgets on collection and transportation, emphasizing the need for cost-effective strategies (Shuku, 2015) (Central Bureau of Statistics, 2020) (Flintoff, 1984).

Cost-Benefit Analysis in Waste Management

Cost-benefit analysis (CBA) helps evaluate the economic feasibility of waste management options by comparing costs and benefits. A benefit-cost ratio above one indicates viable projects. Full cost accounting ensures all direct and indirect costs are considered, enabling better financial planning (Stobierski, 2019) (Duryodhan & Waghmare, 2017).

Empirical Evidence

Studies from Ethiopia and Palestine highlight challenges in fee collection and the economic and environmental benefits of introducing recycling, composting, and sanitary landfills (Lohri, et al., 2014) (Hinde, 2010).Composting is recognized as an eco-friendly solution to reduce organic waste and improve soil health (Atalia, et al., 2015).

Policy Framework in Nepal

Nepal has established policies and acts supporting solid waste management, including the Solid

Waste Management National Policy (1996) (Anon., 1996), Solid Waste Management Act (2011) (Anon., 2011), Local Government Operation Act (2018) (Anon., 2018), and Environmental Protection Act (2019) (Anon., 2019). These frameworks assign responsibilities to local bodies and emphasize public-private partnerships, environmental protection, and sustainable practices (Anon., 1996)

Study Area

Madhyabindu Municipality, located in Nawalparasi (Bardaghat Susta Purba) district of Gandaki Province, lies at the midpoint of the East-West Highway, which inspired its name. The municipality covers 233.35 sq. km and comprises 15 wards with a population of 61,548 across 15,549 households (average size 3.96) based on the 2021 census. It borders Kawasoti Municipality and Hupsekot Rural Municipality to the east, Nisdi Rural Municipality to the north, Binayee Tribeni Rural Municipality to the west, and Chitwan National Park to the south, separated by the Narayani River.

This study focuses on five wards (7, 8, 10, 11, and 12) where solid waste management has recently been introduced. The municipality's extensive forest area provides an abundant source of green and dry leaves, which can be used to supplement organic waste for compost production.

Research Design

Guided by (saunders, et al., 2007)Research Onion Framework, this study adopts a pragmatic philosophy and deductive approach to apply established waste management principles to the context of Madhyabindu Municipality. Using a case study strategy and mixed-methods design, it integrates quantitative data—such as waste generation volumes and financial records—with qualitative insights from stakeholder interviews. The research employs a cross-sectional perspective to capture current practices, with primary data collected through questionnaires and interviews, and secondary data sourced from municipal records, policy documents, and previous studies, enabling a comprehensive evaluation of waste generation, revenue streams, and cost structures.

Data Collection

A mixed-method approach was used, combining structured questionnaires, field observations, and secondary data from municipal records. Primary data were obtained through a formal survey targeting households, businesses, schools, and institutions, gathering quantitative and qualitative information on waste disposal, collection, segregation, and service satisfaction. Secondary data from the (Asian Development Bank, 2013)provided national waste generation benchmarks—households (0.16 kg/capita/day), shops (1.4 kg/unit/day), hotels (5.7 kg/unit/day), schools/colleges (4.0 kg/unit/day), and offices/others (1.4 kg/unit/day)—which were used for comparative analysis. This facilitated assessment of sectoral waste generation patterns, identification of deviations from regional and national averages, and evaluation of gaps in municipal waste management processes.

Data Analysis

Data were processed using Microsoft Excel, SPSS, and other relevant analytical tools to ensure accuracy in interpretation and clarity in presentation. Descriptive statistics—such as means,

standard deviations, and percentage distributions—were applied to summarize waste generation patterns and the composition of revenue and costs. Revenue data were categorized by source, including user fees, recycling sales, compost sales, and penalties, while costs were grouped into collection, transportation, recycling, and landfill operations. Sector-wise waste generation and financial distributions were illustrated using bar and pie charts, allowing for clear visualization of trends, sectoral comparisons, and the identification of areas for improvement.

In addition, a benefit–cost analysis (BCA) was carried out to evaluate the economic viability of the waste management project. BCA is a structured approach to comparing the benefits and costs of a decision or project, with the goal of determining whether the benefits justify the investment (Stobierski, 2019). The process involves calculating net benefits by subtracting total costs from total benefits (Jackson & Strauss, 2007) and expressing the results as a benefit–cost ratio (B/C ratio). In this ratio, values greater than 1 indicate that the benefits outweigh the costs. This method provides a quantitative basis for decision-making, facilitates comparison with alternative projects, and assesses the project's contribution to broader social welfare (Shively, 2012).

3. Results and Discussion

3.1 Waste generation across sectors, their Composition and Recyclability.

Waste Generation across sectors

The study found that waste generation rates vary significantly across different sectors in Madhyabindu Municipality. Household waste generation was measured between 0.277 kg/unit/day (survey data) and 0.428 kg/unit/day (field measurement), which is notably higher than Nepal's national average of 0.17 kg/capita/day reported by Kaza et al. (2018). This indicates that local consumption and waste habits may differ from national trends.

Commercial and institutional sectors showed varied waste generation patterns. Shops averaged around 1.48 kg/unit/day, while hotels and offices showed more fluctuation, with hotels generating up to 3.72 kg/unit/day in the field measurements.

Table 1: Comparison of Results of per unit waste Generation across different sectors

S.No	Sector	ADB benchmark (kg/unit/day)	Questionnaire	Insitu Measurement	ADB vs Questionnaire	ADB vs Insitu
			Mean Value (kg/unit/day)	Mean Value (kg/unit/day)	% Difference	% Difference
I.	Household	0.16	0.277	0.428	+73.13%	+167.50%
II.	Shops	1.4	1.475	1.495	+5.36%	+6.79%
III.	Hotels	5.7	1.498	3.723	−73.70%	−34.68%
IV.	Schools/ Colleges	4	3.68	4.428	−8.00%	+10.70%
V.	Offices/ Others	1.4	1.557	3.768	+11.21%	+169.14%

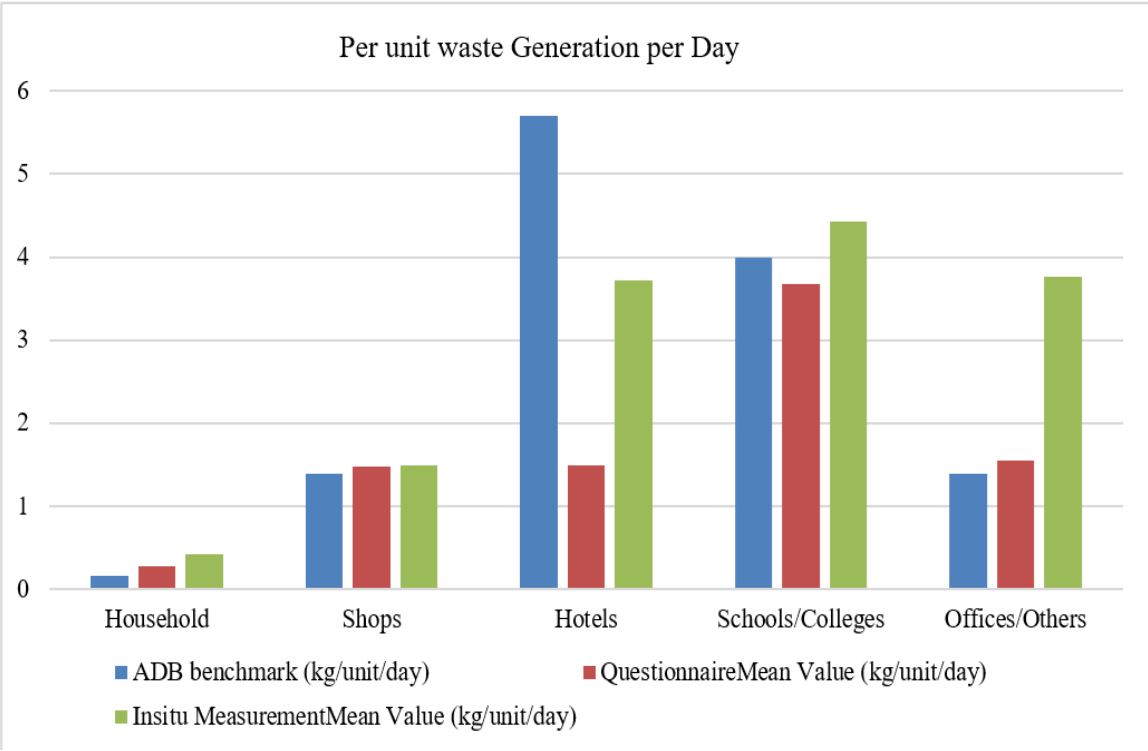

Figure 1:Bar Chart Showing Per Capita Waste Generation per day by different sectors.

Table 2:Descriptive Statics Table for Questionnaire Data

S.No.	Sector	Mean Value Kg/unit/day	Median Value Kg/unit/day	Standard Deviation	Minimum	Maximum
I.	Household	0.277	0.2	0.2867	0.00	2.00
II.	Shops	1.475	1	1.68	0.25	9.00
III.	Hotels	1.498	1	1.789	0.25	7.00
IV.	Schools/Colleges	3.68	2.38	3.29	1.00	11.50
V.	Offices/Others	1.557	1.75	1.091	0.10	3.00

(Questionnaire Data, 2024)

Table 3: Descriptive Statics Table for Insitu Data

S.No.	Sector	Mean Value Kg/unit/day	Median Value Kg/unit/day	Standard Deviation	Minimum	Maximum
I.	Household	0.428	0.34	0.417	0.04	2.35
II.	Shops	1.495	1.18	1.026	0.14	3.84
III.	Hotels	3.723	2.33	3.744	1.32	13.52
IV.	Schools/Colleges	4.428	4.30	0.535	3.85	5.25
V.	Offices/Others	3.768	2.01	4.424	0.62	13.19

(Field Data, 2024)

Organic waste dominates the waste stream, especially in households i.e. 82.96%, emphasizing the potential for composting initiatives. However, a large portion of non-decomposable waste in households i.e. 69.87% remains non-recyclable, indicating a challenge for effective waste diversion.

Table 4: Sectorwise-Waste Recyclability and Disposal

Sector	Organic Waste Recyclable as Compost (%)	Organic Waste to Be Disposed (%)	Non Decomposable Waste Recyclable (%)	Non Decomposable Waste Non-Recyclable (%)
Household Waste	82.96	17.04	30.13	69.87
Commercial Waste	78.30	21.70	49.11	50.89
Institutional Waste	75.55	24.45	57.54	42.46

(Field Data, 2024)

Waste Composition and Recyclability

Waste composition analysis reveals a significantly higher organic fraction across all sectors compared to ADB baseline surveys. For example, household organic waste was measured at 85.69%, compared to the ADB benchmark of 65.24%. This high organic content reflects effective waste segregation practices, supported by separate collection days for decomposable and non-decomposable waste.

The commercial sector shows a balanced composition with almost 50% of non-decomposable waste recyclable, whereas institutional waste demonstrates the highest recyclability for non-decomposable (about 57.54%). However, despite high organic content, a small percentage of organic waste still requires disposal.

Table 5:Result of Comparison of Waste Composition with ADB Baseline Survey

Component	Madhyabindu Municipality			ADB		
	Household Waste (%)	Commercial Waste (%)	Institutional Waste (%)	Household (%)	Commercial (%)	Institutional (%)
Organic	85.69	77.66	72.59	65.24	39.87	19.54
Plastic	7.76	10.68	11.91	11.19	22.16	18.23
Paper	4.27	5.96	12.93	9.29	21.60	44.82
Glass	0.72	-	-	2.83	-	-
Metal	0.65	-	-	1.53	-	-
Textile	0.18	-	-	2.06	-	-
Rubber & Leather	0.23	-	-	1.02	-	-
Others	0.49	5.70	1.29	6.85	-	-

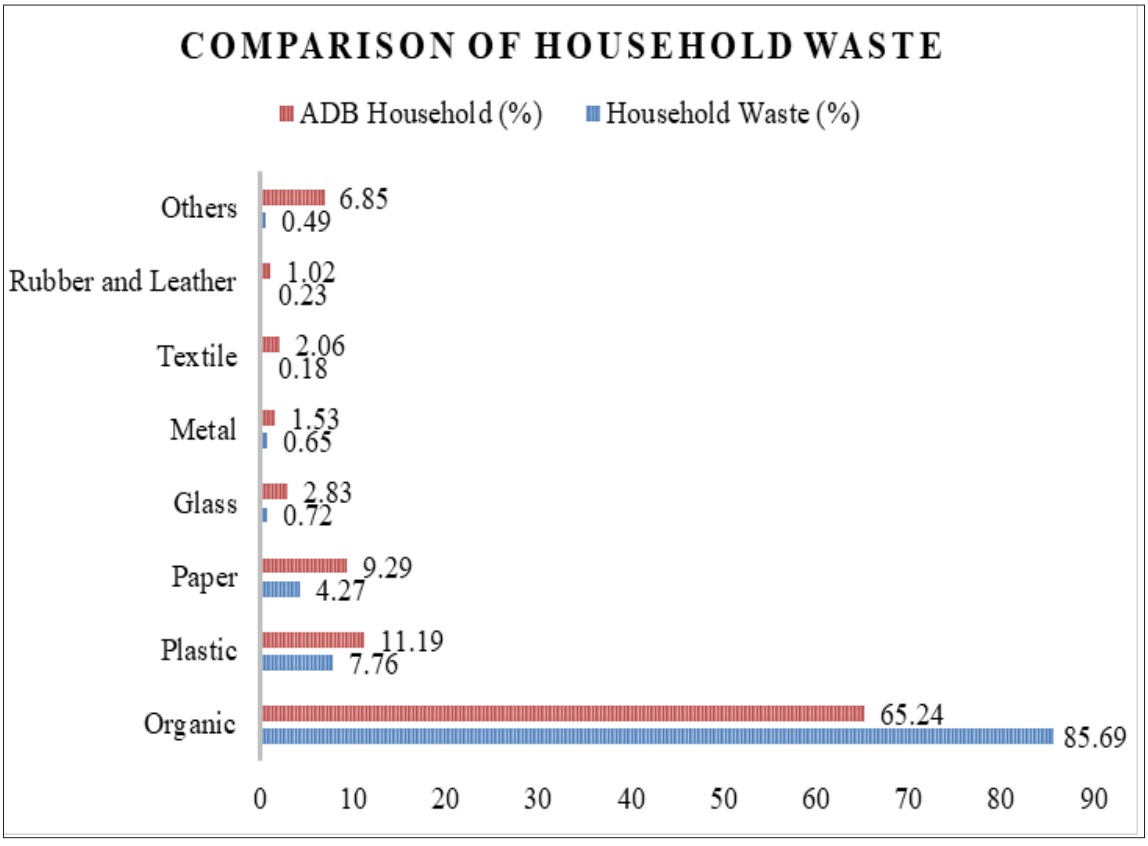

Figure 2: Comparison of Household waste Composition with ADB baseline Survey

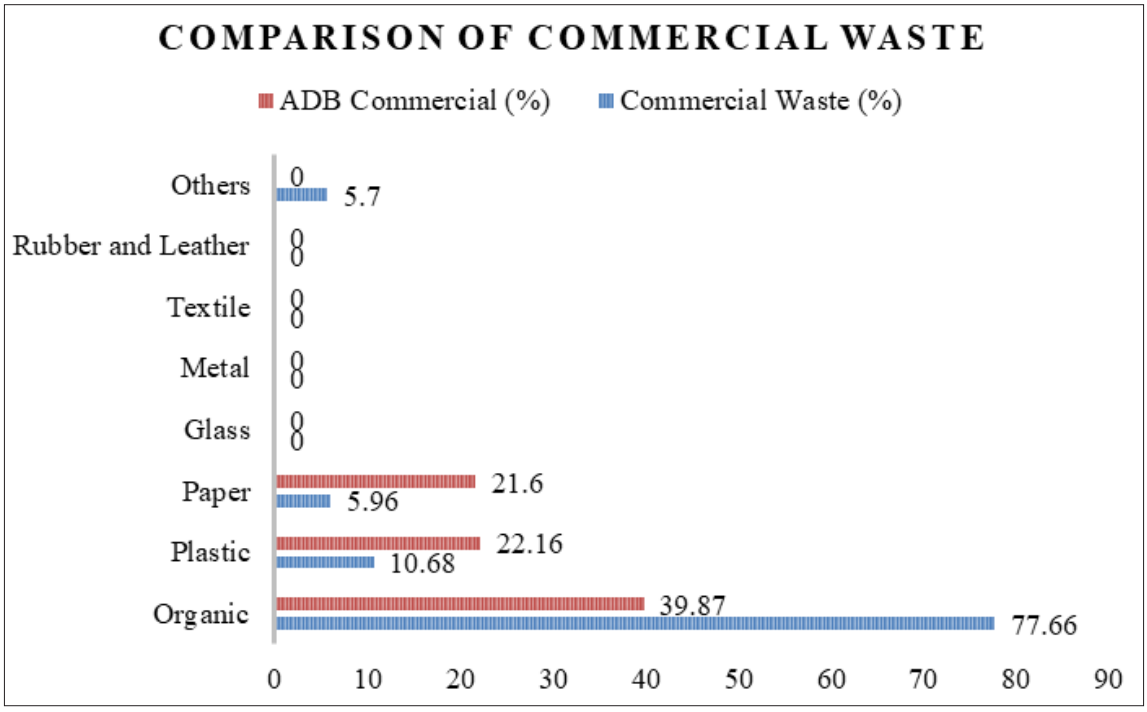

Figure 3: Comparison of Commercial waste composition with ADB baseline survey

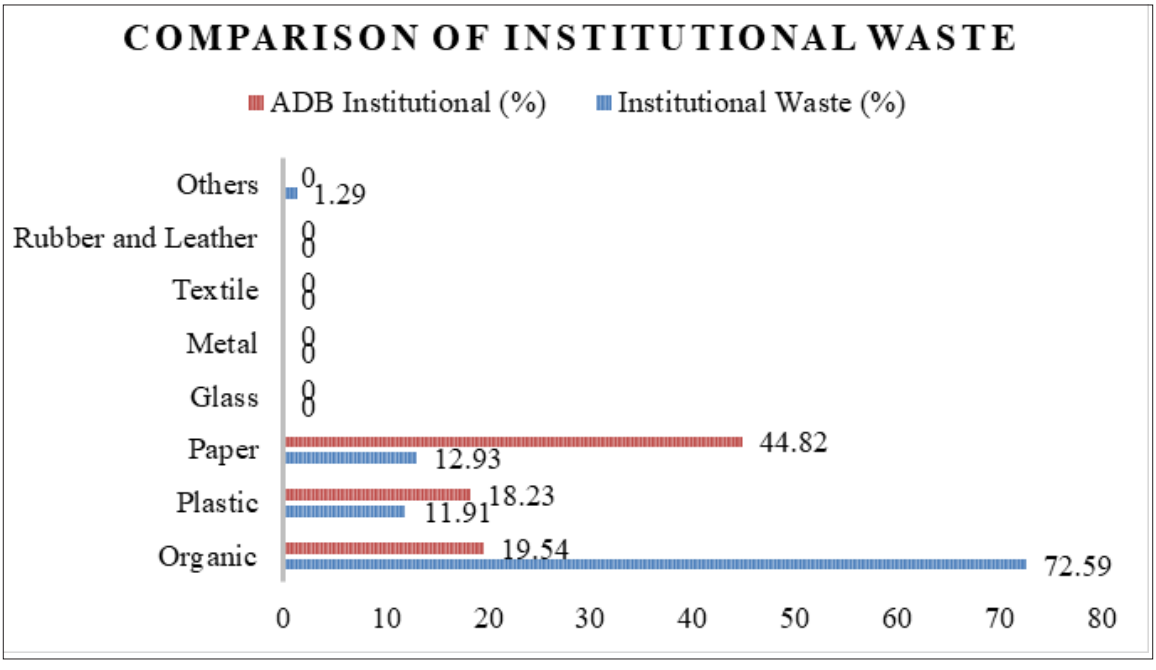

Figure 4:Comparison of Institutional waste Composition with ADB baseline survey

3.2 Revenue Sources and Financial Performance

The solid waste management project's revenue streams are dominated by user fees and organic fertilizer sales. While the theoretical revenue projection over three months was around NPR 2.36 million, actual revenue collected was less than half at NPR 922,820. Notably, no revenue was generated from the sale of recyclable materials or fines during this period, signaling operational gaps.

User fees remain the most reliable income source, followed by modest returns from compost sales. This discrepancy between potential and actual revenue emphasizes the need for better market linkages and enforcement mechanisms to enhance financial sustainability.

Table 6: Revenue sources of Solid waste management Operations

S.N	Revenue source	Revenue as per theoretical framework(NRs)	Estimated Market Value (Based on Stored Inventory) NRs	Actual Collected Revenue (Received by Municipality) NRs	Remarks
1	User Fees	1,356,720	878820	878,820	
2	Sales of Recyclable Materials	528,394.6733	536455.2	0	No sales in 3 months
3	Penalties and Fines	115,348.5888	0	0	No fines and penalties in 3 months
4	Revenue from Organic Fertilizer (Composting)	355,780.558	278,960	44,000	
Total Revenue in 3 months		2,356,243.82	1,694,235.2	922,820	

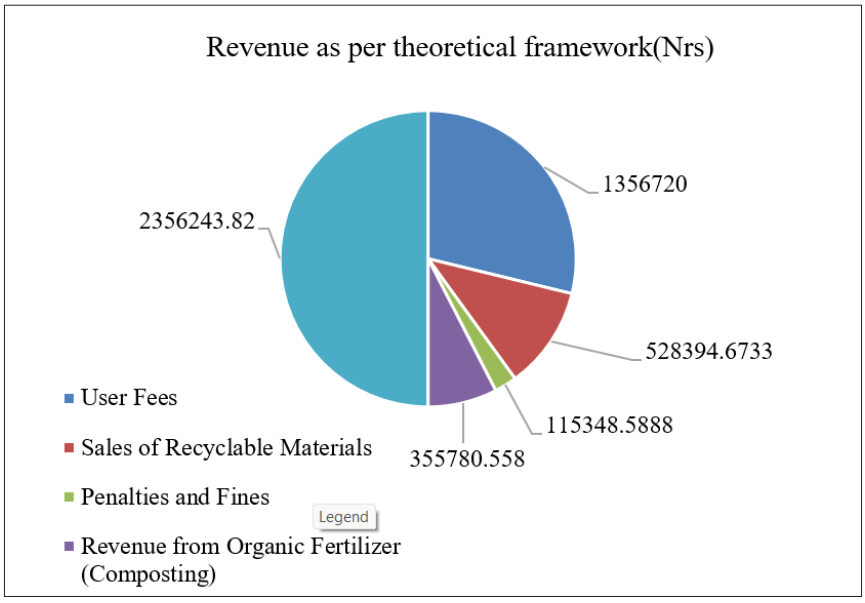

Figure 5: Revenue as per Theoretical Framework

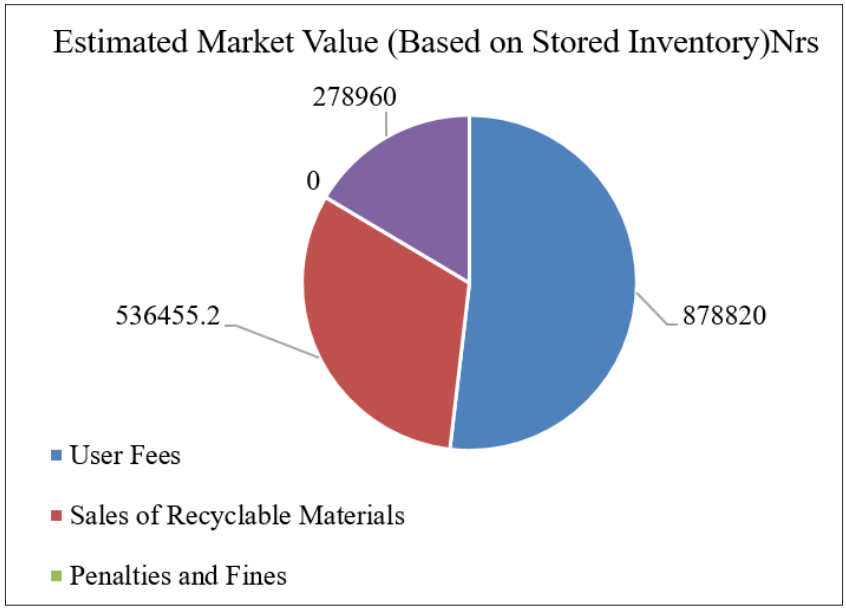

Figure 6: Estimated Market Value (Based on Stored Inventory)

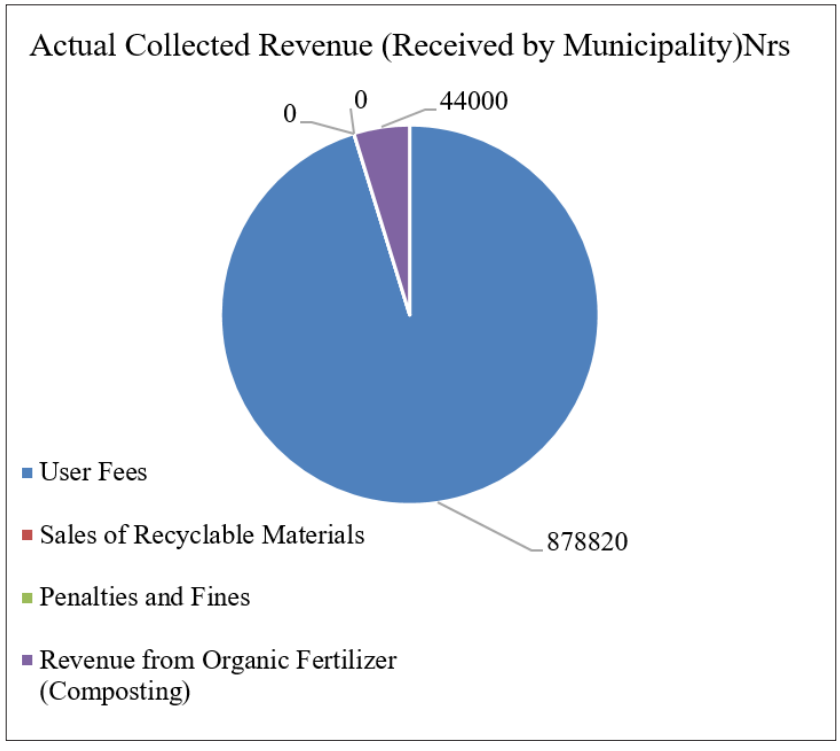

Figure 7: Actual Collected Revenue (Received by Municipality)

3.3 Cost Structure and Benefit-Cost Analysis

The municipality's actual expenditure on solid waste management activities closely matched projections, totaling approximately NPR 2.25 million over three months. Transportation, recycling, and indirect operating costs were the highest expenses, while no costs were recorded for landfilling during this period.

Table 7: Cost structure of solid waste management cost operations

S.N	Cost source	Cost as per theoretical framework	Actual Expenditure (Paid by Municipality)	Remarks
1	Solid Waste Collection Activities (CSW)	187,200	121,800.00	
2	Transportation Activities (CTransport):	319,608.9708	343,620.00	
3	Indirect Operating Costs (CIndirect):	1,117,384.921	956,669.00	
4	Landfilling Activities (CLandfill):	48,372.92963	0	No land filling activities in 3 months
5	Recycling Activities (CRecycling):	499,824	597,546.00	
6	Awareness Programs (CAwareness):	155,940	155,940	
7	Miscellaneous Operating Costs (CMisc.):	81,292.25449	79,471.03	
	Total Cost in three months	**2,409,623.076**	**2,255,046.03**	

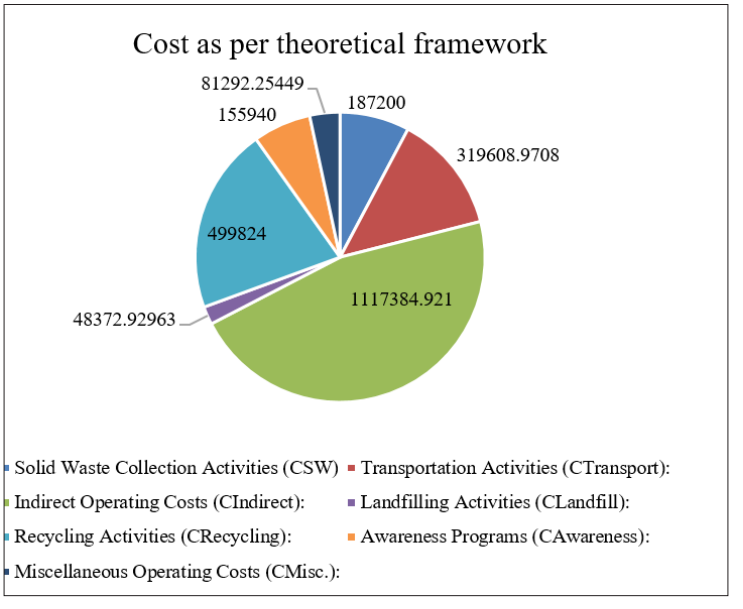

Figure 8: Cost as per Theoretical Framework

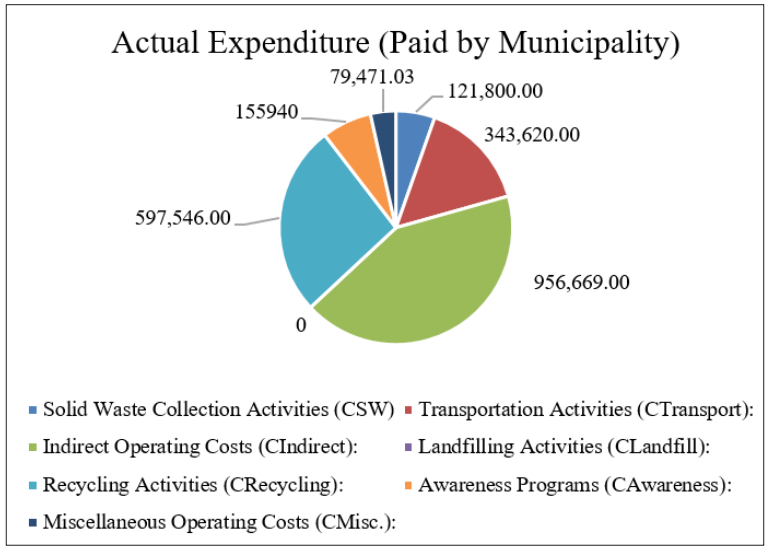

Figure 9: Actual Expenditure (Paid by Municipality)

The Benefit-Cost Ratio (BCR) is a key indicator of financial viability. The theoretical BCR was 0.978, suggesting the system is nearly self-sustaining if all projected revenues were collected. In reality, the actual BCR dropped to 0.409, revealing that for every NPR 1 spent, only about NPR 0.41 was recovered. This highlights a significant funding gap and the need for strategies to improve revenue collection and reduce costs.

4. Discussion

The study shows clear differences in waste generation across sectors in Madhyabindu Municipality, with households producing the largest share, often exceeding national benchmarks. Commercial and institutional sectors perform better in waste segregation, indicating potential for targeted awareness and improved household practices.

Financially, revenue streams—mainly from user fees and compost sales—fall short of projections, largely due to limited recyclable sales and weak fee collection. Cost analysis reveals high spending in transportation, recycling, and indirect operations, with some mismatches between projected and actual expenses.

The benefit-cost ratio tells the clearest story: while the theoretical BCR (0.978) approaches breakeven, the actual BCR (0.409) shows that current operations recover less than half the costs. This gap underscores the need for stronger revenue recovery, cost efficiency, and better integration of recycling markets.

Overall, while the system is established, better cost control, improved fee collection, and targeted waste reduction initiatives could significantly improve both environmental and financial outcomes.

5. Conclusion

Waste generation in Madhyabindu has risen sharply in households, now more than double the national benchmark, while most commercial and institutional sectors remain near national averages.

Revenue depends heavily on user fees and compost sales, but shortfalls in recyclable sales and penalties keep income below potential. High transportation and recycling costs, combined with the low actual Benefit-Cost Ratio (0.409), highlight financial strain despite a near-sustainable theoretical ratio (0.978). Improving fee collection, enforcing penalties, expanding recycling markets, and promoting compost use—supported by awareness programs and regular monitoring can close the revenue cost gap and move the municipality toward a more efficient, resilient waste management system.

5. Conflict of Interest

Author confirms that there lies no conflict of interest.

6. Acknowledgements

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