

## Efficiency and Effectiveness of Waste Management: An Analysis from a Local Budget Policy Perspective

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### Abstract

One of the important challenges in sustainable development goals is waste management, especially in metropolitan cities such as Semarang, which has experienced an increase in population from 1 million to 1.7 million in the last two decades. This study aims to analyze budget allocation, measure efficiency and effectiveness levels, and examine the relationship between budget allocation and waste management performance in Semarang for the period 2021–2024. The methods used are descriptive and analytical quantitative methods. This approach is used to describe the amount of budget allocation for waste management programs. Quantitative analysis is conducted through Data Envelopment Analysis (DEA) to measure efficiency and Cost Effectiveness Analysis (CEA) to measure effectiveness and the relationship between budget allocation and performance achievements. The results of the study show that the budget allocation fluctuated, with the highest in 2022 and the lowest in 2024, with the largest allocation in the sub-activity of waste management through transportation. The DEA analysis shows that 2024 is the most efficient year (score of 1.00) and 2022 is the least efficient year (score of 0.73). The CEA analysis shows that 2024 will be the most effective year with an allocation of Rp69.1 billion, a cost per ton of waste reduction of Rp575,229/ton, a cost per ton of managed waste of Rp160,747/ton, and a cost per ton of recycling of Rp587,554/ton. Pearson's correlation test shows that there is no relationship between the budget amount and performance achievements.

## Introduction

Semarang City is the capital of Central Java Province as well as the fifth largest metropolitan city in Indonesia after Jakarta, Surabaya, Bandung, and Medan with an area of 373.78 km<sup>2</sup> and has 16 sub-districts and 177 villages (BPS, 2023). Based on data released by Badan Pusat Statistik (BPS) Kota Semarang (Semarang City Office of Statistics Indonesia), the population in 2024 amounted to 1,708,833 with a density of 4,571.76 per km<sup>2</sup> with the distribution of population in Semarang City in each sub-district is not evenly distributed. Within Semarang City, East Semarang sub-district is the most densely populated with a density of 12,260.54 people per km<sup>2</sup>, while Tugu sub-district has the lowest density of 1,212.15 people per km<sup>2</sup> (BPS, 2024). One of the causes of population density in Semarang City is the number of public and private universities in Semarang City, which attracts many students from outside the region

to Semarang City, resulting in increased activities and needs such as housing (boarding), dining (culinary), and shopping (Septiani & Susanti, 2023).

Geographically, Semarang City is located on the north coast of Java Island, which is strategic and growing rapidly in the tourism sector. This location makes Semarang an important node of national transportation and encourages local economic growth. One of the positive impacts of this development is the increasing activity of small businesses such as MSMEs, especially in the culinary sector, as well as the increasing number of tourist visits both domestic and foreign (Kurniati et al., 2022). Based on data from BPS, in 2024 there were 109 hotels, 10,528 rooms, and 15,811 beds in Semarang City with an average length of stay of 1.87 nights for foreign guests and 1.34 nights for domestic guests. In 2024, there were 7,345,373 tourist visits, of which 3,935,956 or 53.58% were to culinary attractions. In the culinary sector, the number of restaurants/eateries in 2024 amounted to 1,722 units. In addition, the number of street vendors (PKL) under the supervision of the Department of Trade reached 5,108, with the largest category being incidental vendors (operating once a week), totaling 1,235. The highest concentration of street vendors was found in Central Semarang District, with 1,065 vendors. Furthermore, the number of registered micro-enterprises in the Semarang City Office of Cooperatives and Micro Enterprises amounted to 30,421

However, it is important to keep in mind that this growth will greatly affect waste production in Semarang City. In big cities like Semarang, increased population density and increased economic activity directly contribute to an increase in the amount of waste generated such as larger waste volumes, diverse waste types, pressure on waste management infrastructure, environmental issues, and social and economic challenges (Kurniawan & Fuaddah, 2024). According to SIPSN data (2025), waste generation in Semarang City in 2024 amounted to 434,243.94 tons per year with 60.8% food waste and 17.2% plastic waste. The composition of waste based on the largest source of waste is from households 72%, public facilities 9%, and commerce 8%. In more detail as in Figure 1 and Figure 2.

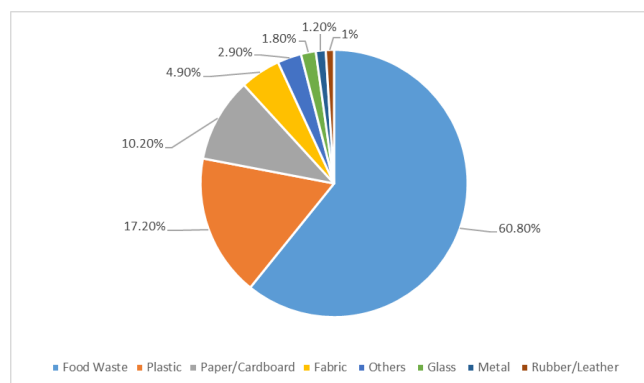


Figure 1. Composition of Municipal Solid Waste in Semarang City by Waste Type in 2024

Source: sipsn.menlhk.go.id (2025)

Based on Semarang Mayor Regulation No. 4 of 2024 concerning the 2023-2042 Waste Management Master Plan, the city of Semarang has only one final processing site (TPA), namely the Jatibarang TPA, located in Kedungpane Village, Mijen District, Semarang City. The Jatibarang FDS has been operating since 1990 until now. This FDS, which has a total area of 46.18 ha, consists of a Landfill Area (active zone) of 23.27 hectares, landfill area (inactive zone) of 3.00 hectares, wastewater treatment plant/leachate pond area of 4.60 hectares, waste

processing area of 4.00 hectares, office area of 0.02 hectares, and other areas of 11.13 hectares. The total waste entering the Jatibarang landfill in 2024 will be 298,954 tons/year (835.1 tons/day), with a waste service level of 66.77% of the total waste volume in Semarang City (BPS, 2025).

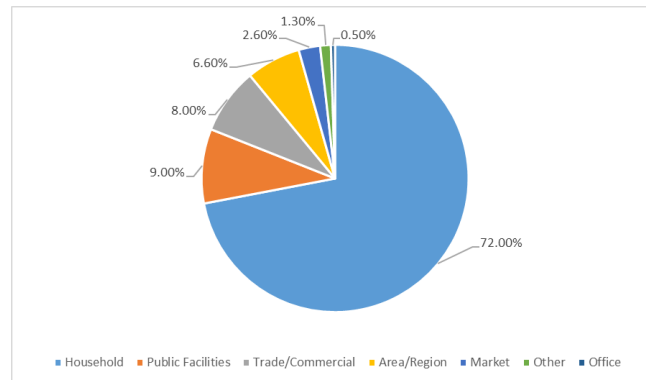


Figure 2. Composition of Municipal Solid Waste in Semarang City by Waste Sources in 2024

Source: sipsn.menlhk.go.id (2025)

Given the increasingly limited land area of the Jatibarang landfill and its decreasing technical lifespan, as well as the high cost of waste transportation, an effective waste management formula from upstream to downstream is needed. In addition, the increase in waste generation has prompted the Semarang City Government to make breakthroughs and innovations in an effort to reduce the amount of waste buried in the Jatibarang landfill. As stated in Law Number 59 of 2024 concerning the National Long-Term Development Plan (RPJPN) 2025–2045, the vision of Indonesia Emas 2045 is to realize Indonesia as a ‘Sovereign, Advanced, and Sustainable Archipelagic Nation.

One of the development agendas, namely Agenda 5 on Socio-Cultural and Ecological Resilience, includes efforts to reform integrated waste management from upstream to downstream. The vision of sustainability also means that the state is committed to continuing to apply the principle of sustainability, which is a conscious and planned effort that integrates environmental, social, and economic aspects into development strategies to ensure the integrity of the environment as well as the safety, capabilities, welfare, and quality of life of current and future generations (Bappenas, 2025). The quality of the environment can be seen from the availability of sufficient green open spaces, healthy and comfortable residential environments, and the preservation of rivers, forests, and air. To maintain this quality, significant costs are required, for example, for integrated waste management, reforestation activities, and water and air quality monitoring (DIKPLHD, 2024). In accordance with the attachment to the Minister of Home Affairs Regulation Number 15 of 2024 concerning Guidelines for the Preparation of the 2025 Regional Budget (APBD), it is stated that local governments allocate a waste management budget for, among other things, waste handling by sorting, collecting, transportation, processing, and final disposal of waste at district/city landfills/waste disposal sites/waste processing sites in accordance with Government Regulation No. 81 of 2012 concerning the Management of Household Waste and Household-like Waste. Waste reduction is achieved by educating and raising awareness among the community and other stakeholders in order to control waste generation.

The APBD functions as an instrument in regional development planning and implementation, including in the environmental sector, where one of the budget allocation focuses is to support waste management efforts. The budget allocation for waste management demonstrates the commitment of the Semarang City government to creating a clean, healthy, and sustainable

environment. As stated in Semarang City Regulation Number 3 of 2024 concerning Amendments to the Regional Revenue and Expenditure Budget for the 2024 Fiscal Year, in the 2024 APBD, the allocation for the Waste Management Program in Semarang City reached IDR 69.11 billion, or around 1.16% of total regional expenditure and 54.59% of the total ceiling of the Dinas Lingkungan Hidup (DLH) (Environmental Agency). This shows that waste management is one of the top priorities in the city's environmental budget. The following is an overview of the total regional expenditure of the Semarang City APBD, the budget allocation for the DLH Kota Semarang, and the Waste Management Program in the Semarang City APBD for the 2021-2024 fiscal years.

Table 1. Total Regional Expenditure, DLH Ceiling, and Budget Allocation for the Semarang City Waste Management Program for Fiscal Years 2021–2024

Fiscal Year	Total Regional Expenditure (Rp)	DLH Ceiling (Rp)	Waste Management Program Ceiling	
			Amount (Rp)	% of DLH Ceiling
2	3	4	5	6 = 5 / 4
2021	5.336.565.925.505	134.161.035.334	85.037.552.900	63,38%
2022	5.218.296.302.859	150.505.840.237	97.016.593.824	64,46%
2023	5.702.916.601.809	155.735.139.133	93.830.125.080	60,25%
2024	5.957.063.431.486	126.603.494.587	69.115.052.158	54,59%

Source: Semarang City Regulation on Amendments to the Regional Budget

Table 1 shows that the DLH ceiling for Semarang City increased from 2021 to 2023, then decreased by around 19% in 2024. This decline was accompanied by a decrease in the budget allocation for waste management programs, which had been gradually declining since 2022 and fell more sharply in 2024. The ratio of the waste management program budget to the DLH ceiling also shows a decline, from consistently above 60% in 2021–2023 to below 60% in 2024. This trend illustrates a shift in the proportion of environmental spending, which can be seen further in Figure 3.

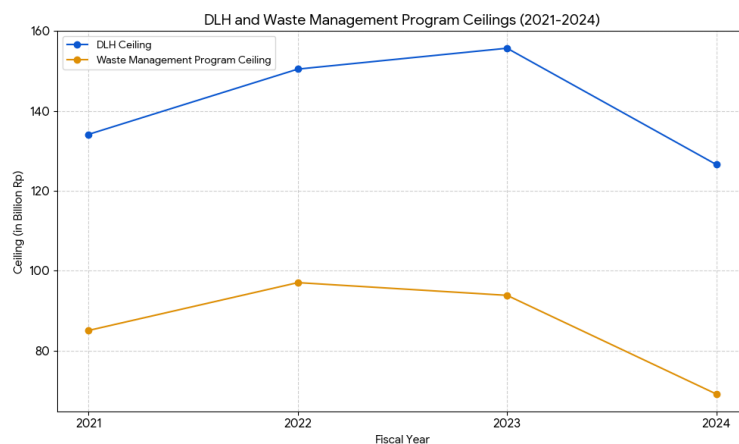


Figure 3. DLH Budget Allocation and Waste Management Program

Source: Analysis Results, 2025

Based on Table 1 and Fig. 3, it is explained that the budget allocation for the DLH Kota Semarang and the waste management program has fluctuated, which will certainly have an impact on the work program plans to be implemented by the DLH Kota Semarang in the

relevant fiscal year. Therefore, a study is needed on the efficiency and effectiveness of the use of the APBD funds for waste management in Semarang City and the correlation between budget allocation and waste management performance achievements. Furthermore, the results of the study will be used to provide policy recommendations to improve the sustainability of the waste management system.

## Methods

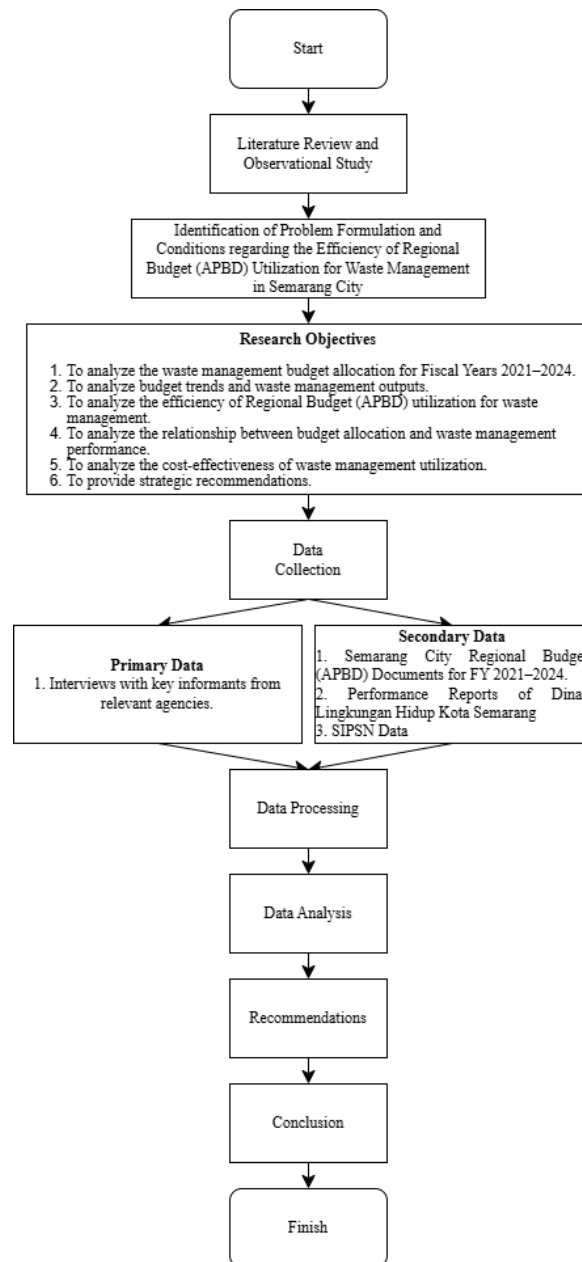


Figure 4. Research flowchart

The approach used in this study is a descriptive and analytical quantitative approach. Quantitative research is used in this study because the data collected is in the form of numbers and is analyzed using statistical techniques. This research relies on numerical data such as budget amounts, waste volume, waste reduction percentages, recycling, and other performance indicators. The Descriptive Quantitative Approach aims to describe the budget allocation for

waste management programs. The data collected will then be presented in the form of tables, graphs, and descriptive statistics (averages, percentages, trends). The Quantitative Analysis approach is used to assess the efficiency of waste management budget allocation. This analysis compares input (budget allocation amount) with output (generation, reduction, handling, management, recycling, and recycling rate), and assesses whether the budget allocation provides optimal results. This type of research is descriptive and evaluative, describing the budget allocation for waste management programs and evaluating the performance of waste management policies in Semarang City in order to provide data-based policy recommendations.

This research was conducted in Semarang City, focusing on the agencies involved in the planning, budgeting, and implementation of waste management programs, namely the Badan Perencanaan Pembangunan Daerah (Bappeda) Kota Semarang (Regional Development Planning Agency), Badan Pengelolaan Keuangan dan Aset Daerah (BPKAD) Kota Semarang (Regional Financial and Asset Management Agency), and Dinas Lingkungan Hidup (DLH) Kota Semarang (Environmental Agency). The research was conducted from March to May 2025, with data collected from the 2021-2024 regional budget (APBD) documents.

The data used in this study were primary and secondary data. Primary data were collected through observation at the Jatibarang landfill and interviews with informants from relevant agencies, including officials or staff at the DLH, managers of the Jatibarang landfill, planners in the Regional Development Control and Evaluation Planning Division of Bappeda, and Financial Analysts in the Budget and Financial Support Division of BPKAD. Secondary data was collected from official documents and reports from the Semarang City Government in the form of the Semarang City APBD for the 2021-2024 fiscal year, Government Agency Performance Report (LKjIP) of the Semarang City Environmental Agency (DLH), data on waste volume, reduction, recycling, and related academic literature.

Data analysis techniques are methods or ways used to process data so that it becomes information that is easy to understand and can be used in finding solutions to a problem (Ulfah et al., 2022). The stages of data analysis in this study consisted of several steps, namely: Data reduction, which is the process of summarizing, selecting key points, focusing on important aspects relevant to the research topic, and looking for themes and patterns. This stage aims to provide a clearer picture and facilitate further data collection (Warsono et al., 2022). This stage covers programs, activities, sub-activities, and budget allocations for waste management programs. The sorting/selection of the data was carried out using the Semarang City APBD document for Fiscal Year 2021 - 2024 as the reference. Descriptive statistical analysis aimed at providing an initial overview of the annual trends in budget allocation, waste generation (tons), waste reduction (tons), waste management (tons), and waste recycling (tons) during the 2021–2024 period. The data is presented in tables and trend lines using Microsoft Excel. Efficiency analysis aims to measure the efficiency of budget utilization in relation to the annual performance of waste management using the Data Envelopment Analysis (DEA) approach. The DEA model applied in this analysis is input-oriented Constant Return to Scale (CRS), which calculates how efficiently inputs (budget allocations) are used to produce various outputs in the field of waste management, such as the amount of waste that has been successfully handled or managed, the percentage of reduction, the amount of waste recycled, and the recycling rate. The results of the DEA analysis will produce an annual efficiency score ranging from 0 to 1, with a score of 1 indicating maximum efficiency. This analysis was conducted using MaxDEA software (Nandito, 2019).

Cost effectiveness analysis, this method aims to evaluate the economic value of waste management results. Calculations are made by comparing budget allocations to specific

outputs, such as the cost per ton of waste reduction, the cost per ton of waste managed, and the cost per ton of recycling. This analysis aims to assess which aspects of waste management provide the most efficient results in terms of financing. Pearson correlation analysis aims to test the linear relationship between budget allocation and waste management performance variables. This is to explain the extent to which budget allocation affects waste management results statistically. The output generated is in the form of a correlation coefficient (r) and significance level (p-value), which are analyzed using SPSS (Sari et al., 2023). With the analytical approach steps described above, this study is expected to provide a comprehensive picture of the efficiency and effectiveness of waste management based on the amount of budget allocation from the APBD, as well as to provide a basis for recommendations for future policy improvements.

## Results and Discussion

### *Analysis of Waste Management Budget Allocation for 2021–2024*

Based on the Semarang City Regional Budget (APBD) documents for the 2021–2024 fiscal year and the Budget Implementation Document (DPA) of the Semarang City Environmental Agency (DLH), programs, activities, and sub-activities directly related to waste management were identified. These programs cover various efforts in waste management, which are the main focus of the budget. Road infrastructure development programs and other sectors not directly related to waste management are not included in the analysis. Thus, the budget allocated for waste management can be identified specifically, enabling an assessment of the efficiency of APBD use in this sector and its contribution to economic and environmental outcomes. The following are the results of data reduction based on waste management programs, activities, and sub-activities as stated in the Semarang City APBD documents for Fiscal Years 2021–2024.

Table 2. Waste Management Programs, Activities, and Sub-Activities

<b>Regional Government Agency</b>	<b>Program</b>	<b>Activity</b>	<b>Sub Activity</b>
Dinas Lingkungan Hidup	Waste Management Program	Waste Management	Enhancing Community Participation in Waste Management
			Coordination and Synchronization of the Provision of Waste Management Infrastructure and Facilities
			Provision of Waste Management Facilities and Infrastructure in District/City Final Disposal Sites (TPA/TPST/SPA)
			Formulation of Regional Plans, Policies, and Strategies for District/City Waste Management
			Waste Handling through Transportation
			Waste Reduction through Waste Recycling
			Formulation of Cooperation Policies for Waste Management

Source: Analysis Results, 2025

Based on Table 2, the waste management program in Semarang City for 2021-2024 is under the jurisdiction of one Regional Apparatus Organization, namely the Semarang City Environment Agency (DLH). This waste management policy is reflected in one program, one activity, and seven sub-activities. The following are the details of the Waste Management Program, Activities, and Sub-Activities along with the budget allocation for the 2021-2024 fiscal year.

Table 3. Waste management budget allocation based on SKPD, Program, Activities, and Sub-Activities for the 2021-2024 fiscal year

Sub-Activities	2021	2022	2023	2024
Environmental Service				
Waste Management Program	85.037.552.90 0	97.016.593.82 4	93.830.125.08 0	69.115.052.15 8
Waste Management	85.037.552.90 0	97.016.593.82 4	93.830.125.08 0	69.115.052.15 8
Enhancing Community Participation in Waste Management	167.163.870	570.866.400	1.439.917.933	1.293.498.400
Coordination and Synchronization of the Provision of Waste Management Infrastructure and Facilities	9.513.785.045	9.221.749.362	16.914.878.02 8	4.602.455.568
Provision of Waste Management Facilities and Infrastructure in District/City Final Disposal Sites (TPA/TPST/SPA)	9.473.736.377	17.554.555.85 6	5.322.603.024	8.914.580.649
Formulation of Regional Plans, Policies, and Strategies for District/City Waste Management	26.458.907	100.000.000	97.482.203	97.316.340
Waste Handling through Transportation	64.446.090.06 5	67.263.577.18 9	67.833.034.20 9	51.860.215.93 7
Waste Reduction through Waste Recycling	505.363.876	819.823.769	736.189.237	889.576.100
Formulation of Cooperation Policies for Waste Management	904.954.760	1.486.021.248	1.486.020.446	1.457.409.164

Source: Semarang City Regional Regulation on APBD Amendments, processed

Based on the Semarang City APBD document for the 2021–2024 fiscal year, the budget allocation for waste management shows a fluctuating trend. In 2021, the budget reached IDR 85 billion and increased in 2022 to IDR 97 billion, but decreased again in 2023 and 2024 to IDR 93 billion and IDR 69 billion, respectively. This decline warrants attention given that the volume of waste generated in Semarang City tends to increase every year. Hasan et al. (2020) note that compared to other major cities, Semarang City's waste management budget allocation of Rp69 billion in 2024 is relatively low. For example, in 2019, the city of Surabaya allocated a budget of Rp238.6 billion or 2.5% of its total regional budget, which is far above the amount allocated by the city of Semarang. The city of Medan also showed a similar commitment with an allocation of Rp137.3 billion or 2.2% of the APBD in the same year. Although the data for the city of Semarang does not include the percentage of the total APBD, the decline in the

budget from Rp97 billion in 2022 to Rp69 billion in 2024 is noteworthy, especially considering the trend of increasing waste volume every year. This decrease in allocation indicates a weak priority for waste management in regional fiscal planning, especially when compared to cities that have actually increased their waste management spending as a sign of their seriousness in addressing environmental challenges. Further analysis shows that most of the budget is allocated for waste transportation, accounting for more than 70% of the total waste management budget each year. Meanwhile, waste reduction programs through recycling and increased community participation receive a relatively small portion of the budget, less than 2%. According to Sapanli et al. (2023), this indicates that Semarang City's waste management strategy is still dominated by an end-of-pipe approach, which focuses on transportation and disposal rather than reduction at the source or the application of the circular economy concept.

### ***Waste Management Budget and Output Trends***

This analysis technique aims to provide an initial overview of the annual trends in budget allocation, waste generation (tons), waste reduction (tons), waste handling (tons), and waste recycling (tons) during the 2021-2024 period. The budget allocation amounts were obtained from the Semarang City Regional Regulation on APBD Changes for the 2021-2024 period, and waste data was obtained from the National Waste Management Information System (Sistem Informasi Pengelolaan Sampah Nasional (SIPSN)), a platform used to collect and manage data and information related to waste management activities in Indonesia, including generation, reduction, handling, and management of waste in each region. Through SIPN, the public can directly view or monitor waste management performance, such as the percentage of success in reduction and handling in waste management.

Table 4. Budget allocation and waste management performance achievements for 2021–2024

Year	Regional Budget (Rp)	Waste Generation (tons/year)	Waste Reduction (tons/year)	% Reduction	Waste Handling (tons/year)	% Handling	Managed Waste (tons/year)	% Managed	Waste Recycling (tons/year)	Waste as Raw Material (tons/year)	Recycling Rate
1	2	3	4	5=4/3	6	7=6/3	8=4+6	9=8/3	10	11	12=(10+11)/3
2021	85,037,552,900	430749.75	101951.98	23.67	319718.1	74.22	421670.08	97.89	25459.75	343.1	5.99
2022	97,016,593,824	431085.22	112850.45	26.18	314187.98	72.88	427038.43	99.06	60774.61	297.48	14.17
2023	93,830,125,080	431534.65	116591.38	27.02	310739.85	72.01	427331.23	99.03	108332.04	317.55	25.18
2024	69,115,052,158	434243.97	120152.3	27.67	309809.86	71.34	429962.16	99.01	117631.87	317.55	27.16

Source: Semarang City Regional Regulation on APBD Amendments, processed

Based on Table 4, it can be explained that the amount of budget allocation for waste management in 2021-2024 shows fluctuations. The highest allocation was recorded in 2022 at IDR 97.02 billion, while the lowest allocation was in 2024 at IDR 69.12 billion. The largest decrease was in the sub-activities of waste management through transportation and coordination and synchronization of the provision of waste management infrastructure and facilities. Although the budget allocation decreased in 2023 and 2024, the waste management

output indicators showed an improving trend, such as the efficiency of waste reduction from the total amount generated, which increased from 23.67% in 2021 by 4% to 27.67% in 2024, and an increase in recycling volume, which has increased the economic value of waste from 25,459.75 tons/year in 2021 to 117,631.87 tons/year or 362% in 2024. In more detail, the improvement in waste management indicators despite the decline in budget allocation is as follows.

Table 5. Improvement in Environmental Output Indicators for Waste Management in Semarang City from 2021 to 2024

Indicator	2021	2024	Increase / (Decrease)	Remarks
Waste Reduction (tons/year)	101.951,98	120.152,30	18.200,32	The effectiveness of the reduce and reuse program is increasing.
Percentage of Waste Reduction (%)	23,67%	27,67%	4,00%	The efficiency of waste reduction from total waste generation is increasing.
Waste Recycling (tons/year)	25.459,75	117.631,87	92.172,12	Increase in recycling volume, enhancing the economic value of waste.
Recycling rate (%)	5,99%	27,16%	21,17%	The proportion of recycled waste is increasing.
Managed Waste (tons/year)	421.670,08	429.962,16	8.292,08	The coverage of waste management is increasing.
Percentage of Managed Waste (%)	97,89%	99,01%	1,12%	The management system is still capable of handling almost all waste generation.

Source: Analysis Results, 2025

From an environmental perspective, annual waste generation from 2021 to 2024 is expected to remain stable at between 430,749.75 tons/year and 434,243.97 tons/year. However, the volume of waste reduction increased from 101,951.98 tons/year in 2021 to 120,152.30 tons/year in 2024, with the reduction percentage increasing from 23.67% to 27.67%. This condition shows an increase in the effectiveness of the waste reduction program even though the budget allocation has decreased. In terms of waste handling volume, there was a decrease from 319,718.10 tons/year in 2021 to 309,809.86 tons/year in 2024. Despite this decrease, the total amount of waste successfully managed increased from 97.89% to 99.01%. The most significant increase was seen in the waste recycling indicator. The volume of recycled waste increased almost fivefold from 25,459.75 tons/year in 2021 to 117,631.87 tons/year in 2024. This achievement had a direct impact on the increase in the recycling rate from 5.99% to 27.16%, with an average recycling rate during 2021-2024 reaching 18.62%, indicating an increase in capacity and efficiency in the reuse of waste as a resource. Based on the descriptive analysis, it can be concluded that there was a decrease in budget allocation in 2023 and 2024, but waste management performance improved. This indicates that a more targeted and results-based

waste management strategy is beginning to have a real impact on the environment, even amid limited budget allocations.

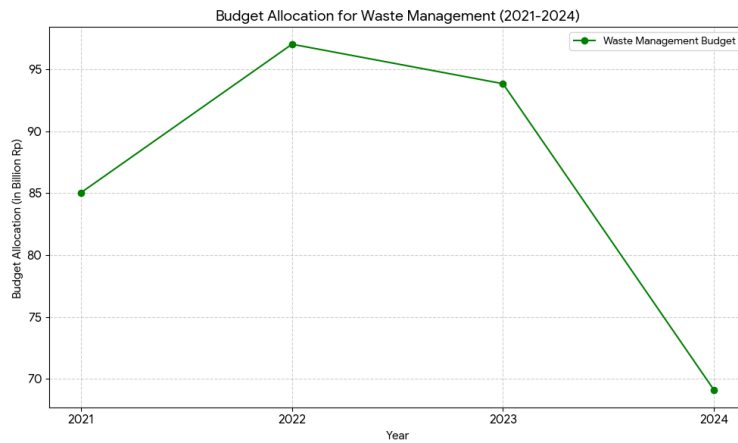


Figure 5. Budget Allocation for Waste Management Chart

Source: Analysis Results, 2025

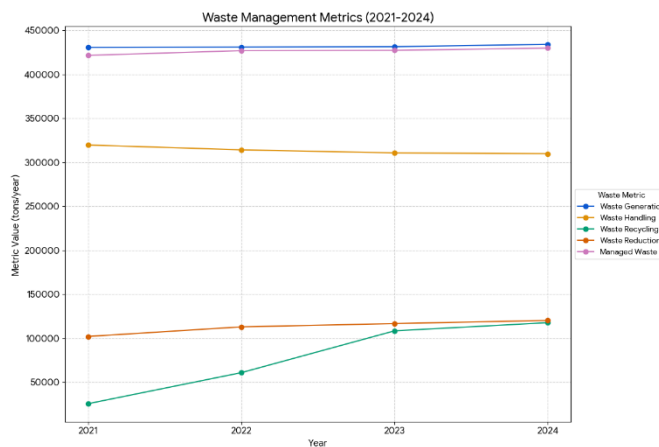


Figure 6. Waste Management Performance Achievement Allocation Chart

Source: Analysis Results, 2025



Figure 7. Percentage of Waste Reduction, Handling, Management, and Recycling Rate Chart

Source: Analysis Results, 2025

The visualization in Figure 5 shows a downward trend in the budget in 2023 and 2024, while the visualizations in Figure 6 and Figure 7 show an increase in environmental output, particularly in waste reduction and recycling rates, indicating that a more targeted waste management strategy is beginning to have a real impact on the environment even with limited budget allocations. According to Bappenas (2024), the recycling rate itself shows how effective a system is at managing end-of-life products and materials, then converting those materials back into usable and exploitable forms. The findings of this study show that despite an increase in the waste management budget allocation in Semarang City for the 2021–2024 period, this increase has not been fully proportional to the achievement of environmental output indicators, particularly in terms of recycling and recycling rates. This is reinforced by a report from Systemiq (2021), which shows that budget increases without accompanying policy innovations and strengthened community participation tend to be ineffective in improving waste management performance. The report emphasizes that the main challenges of waste management in Indonesia are not only limited budgets, but also weak governance, low community participation, and a lack of policy innovation in the regions. A study by Meganingrum et al. (2025) shows that regions with digital technology integration and participatory approaches, such as Malang City and Banyuwangi Regency, have been able to achieve the highest recycling rates of up to 28.05%. This achievement reflects that community collaboration, infrastructure support, and the implementation of performance-based incentive policies have been key factors in driving significant improvements in waste management in recent years. However, when compared to the national average recycling rate, Semarang City's achievement in 2024 exceeded the national average of around 9.5% (SIPSN, 2024). This achievement even exceeded the national recycling rate baseline of 5% (Bappenas, 2024). This reinforces the fact that the success of increasing waste management output in a region is not solely determined by the size of the budget, but also by the effectiveness of governance, policy innovation, and community participation. The city of Semarang, despite experiencing fluctuations and a decline in budget allocation in 2023–2024, was still able to show a significant increase in recycling indicators and recycling rates. This shows that management strategies, optimization of waste banks, and digitization of reporting have played an important role in achieving these results.

### ***Efficiency of Local Budget Fund Use for Waste Management***

Data Envelopment Analysis (DEA) is a non-parametric approach to evaluating the performance of a collection of homogeneous entities called Decision Making Units (DMUs). DEA is a method of comparing the value of the output of a process with the value of its input. It is considered efficient if the efficiency value obtained is 1 and is considered inefficient if the efficiency value is closer to 0 (Utari et al., 2023). Efficiency value criteria are divided into four categories, namely efficiency values  $< 0.600$  (inefficient category), efficiency values between  $0.600 - < 0.8000$  (less efficient category), efficiency values between  $0.8000 - < 1.000$  is categorized as moderately efficient, and an efficiency value of 1.000 is categorized as efficient (Prasetya & Budiwitjaksono, 2023). Based on the results of the analysis using the MaxDEA application, the following results were obtained.

Tabel 6. MaxDEA Efficiency Score

Year	Score	Status
2021	0,85	Moderately Efficient
2022	0,73	Less Efficient
2023	0,74	Less Efficient
2024	1,00	Efficient

Based on Table 6, 2024 will be the most efficient year, as indicated by the smallest budget allocation of Rp69 million, but it will be able to produce the best performance in all output indicators. One of them is the highest recycling rate indicator, reaching 27.16%. This condition shows that in 2024, the budget allocation for waste management will be used optimally and on target. Meanwhile, in 2021-2023, the efficiency value is  $< 1$ , indicating that the output produced is not yet optimal compared to the input used. The output performance in 2024 also shows optimal results across all indicators. The recycling rate is recorded at 27.16%, which exceeds the national baseline of 5% (Bappenas, 2024). The volume of recycling jumped from 25,459.75 tons in 2021 to 117,631.87 tons in 2024. The percentage of waste reduction increased from 23.67% to 27.67%, and the percentage of managed waste remained consistently above 99%. The volume of waste reduction also increased from 101,951.98 tons to 120,152.30 tons in the same period. Conversely, in 2022 and 2023, despite a larger budget allocation of Rp97 billion and Rp94 billion, the efficiency score was lower at 0.73 and 0.74. Output indicators such as the recycling rate in 2022 were only 14.17%, and the volume of recycling was not as optimal as in 2024. This shows that budget increases without policy innovation, good governance, and community participation do not necessarily result in optimal efficiency and environmental output (Systemiq, 2021).

Asqia (2024) emphasizes that the efficiency of waste management is more influenced by institutional innovation, system digitalization, and planning integration than simply the size of the budget. In addition, Bappenas (2022) also identifies a number of quick wins that can accelerate waste management reform, such as improving the quality of planning, strengthening stakeholder capacity, improving data management, and institutional flexibility. The city of Semarang, with the highest efficiency achievement in 2024, can be used as an example of good practice in effectively implementing these strategies at the regional level. Thus, DEA analysis integrated with national output and insight data reinforces the argument that the efficiency of APBD fund use in waste management is greatly influenced by the quality of governance, strategic innovation, and planning integration, rather than simply the size of the budget.

### **Cost Effectiveness Analysis**

This analysis aims to measure the efficiency of the use of the waste management budget allocation in producing waste management outputs or indicator achievements, both in terms of quantity and quality of environmental management. This effectiveness analysis is measured by comparing the waste management budget allocation with annual waste reduction, annual managed waste, and annual waste recycling.

Table 7. Cost Effectiveness of Waste Management

Tahun	Budget Allocation (Rp)	Cost per Ton of Waste Reduced (Rp/ton)	Cost per Ton of Waste Managed (Rp/ton)	Cost per Ton of Waste Recycled (Rp/ton)
2021	85.037.552.900	834.094	201.668,45	3.340.078,08
2022	97.016.593.824	859.692	227.184,69	1.596.334,29

2023	93.830.125.080	804.778	219.572,36	866.134,57
2024	69.115.052.158	575.229	160.746,83	587.553,80

Source: Analysis Results, 2025

Based on Table 7, it shows that 2024 will be an important year in demonstrating the effectiveness of Semarang City's waste management policy, with the lowest budget allocation during the 2021-2024 period, namely IDR 69.1 billion. However, its effectiveness is at its best, with the cost per ton of waste reduction falling from IDR 834,094/ton in 2021 to IDR 575,229/ton in 2024. Similarly, the cost per ton of managed waste in 2021 was Rp201,668/ton, which will decrease to Rp160,747/ton in 2024. The best performance achievement was in the cost per ton of waste recycling, which was Rp3,340,078/ton in 2021, decreasing by Rp2,752,524/ton or 468.5% to Rp587,554/ton in 2024. This performance achievement shows that there has been an increase in efficiency in waste management. This achievement also shows an improvement in waste management performance, such as changes in community behavior towards a circular economy, such as the implementation of reduction strategies at the source (reduce), reuse of items that are still usable (reuse), and an increase in recycling capacity (recycle). This phenomenon indicates that the effectiveness of waste management does not solely depend on the size of the budget, but rather on the quality of management, program innovation, and targeted policy strategies. This is in line with Saputro (2023), who wrote that improvements in waste management efficiency are largely determined by the application of appropriate technology, institutional strengthening, and active community participation in a sustainable waste management system.

In general, improving cost effectiveness does not always depend on the size of the allocated budget. This indicates the importance of effective management and targeted policy strategies. In other words, the effectiveness of waste management is not only determined by the size of the budget allocation, but also by the quality of governance, program innovation, and community participation in the waste management system. The results of this study support the transition from an end-of-pipe (treatment-based) approach to a preventive and circular approach, such as reducing waste at the source and increasing waste recycling (Sapanli et al., 2023). Therefore, government policies that support the implementation of a circular economy should be a priority in Semarang City's strategic waste management plan.

### ***Analysis of the Relationship Between Local Government Budget Allocation and Waste Management Performance***

The next step was to test the relationship between the amount of budget allocation and waste management performance, namely by using Pearson's correlation analysis with the independent variable (X) being the amount of budget allocation for waste management and the dependent variable (Y) including waste generation, waste reduction, reduction percentage, waste handling, percentage of handling, amount of managed waste, percentage of managed waste, recycling, raw materials from processing, and recycling rate. The following are the results of the Pearson correlation analysis between budget allocation and waste management performance variables in Semarang City during 2021–2024:

Table 8. Results of Pearson correlation analysis with SPSS

Variabel	Koefisien Korelasi (r)	P-Value
Waste Generation	-0,842	0,158
Waste Reduction	-0,283	0,717
Percentage of Waste Reduction	-0,245	0,755

Waste Handling	0,251	0,749
Percentage of Waste Handling	0,390	0,610
Managed Waste	-0,317	0,683
Percentage of Managed Waste	0,095	0,905
Waste Recycling	-0,354	0,646
Waste as Raw Material	-0,353	0,647
<i>Recycling rate</i>	-0,348	0,652

Source: Analysis Results, 2025

Based on Table 8, the Pearson correlation coefficient ( $r$ ) between budget allocation and waste management performance indicators in Semarang City during 2021–2024 varies, ranging from -0.842 for waste generation to 0.454 for waste recycling. However, all  $p$ -values are above 0.05, which means that there is no statistically significant relationship between the amount of budget allocation and waste management performance indicators. Negative coefficient values for variables such as waste generation of 0.842 and processed raw materials of -0.353 indicate a reverse relationship, although not significant. Meanwhile, positive coefficients in variables such as waste recycling of 0.454 and waste reduction of 0.283 indicate a unidirectional relationship, but this is also not significant. Therefore, the results of this analysis show that an increase in budget allocation does not necessarily correlate with an increase in waste management performance. This condition may be due to inefficiency in budget utilization, or the influence of other factors such as technical policies, governance, community participation, or the involvement of non-governmental organizations in supporting effective and sustainable waste management, which were not measured in this study. Therefore, further in-depth analysis is needed during the planning, budget allocation, and implementation of the waste management budget.

Based on this, it indicates that an increase or decrease in budget allocation is not necessarily followed by a significant change in the output performance of waste management. Saputro (2023) concludes that waste management does not only depend on the size of the budget, but also greatly depends on the quality of governance, community participation, integrated systems, and technological and policy innovations. Furthermore, these results reinforce Bappenas' (2022) argument that institutional fragmentation, lack of planning integration, and weak supervision and evaluation are the main challenges of waste management in Indonesia. The city of Semarang, despite budget fluctuations, has been able to show an upward trend in environmental output through strategy optimization, reporting system digitalization, and strengthening of waste banks, rather than solely through budget increases. This is in line with the concept of Integrated Sustainable Waste Management, which emphasizes the importance of synergy between institutional, technical, and social aspects in achieving efficient and sustainable waste management (Fadilla & Kriswibowo, 2022). Thus, the results of Pearson's correlation analysis in this study confirm that the efficiency and effectiveness of regional waste management are more determined by the quality of governance, innovation, and multi-stakeholder collaboration, rather than simply the size of the budget allocation. Based on the results of the analysis of the use of the Semarang City Regional Revenue and Expenditure Budget (APBD) in waste management during the 2021–2024 period, several strategic recommendations can be made as follows: Preparation and implementation of a performance-based budget for the environmental sector. The BPKAD of Semarang City should develop guidelines for performance-based budgeting in the environmental sector so that the allocation of the budget for the environment, particularly for waste management, is based on measurable

outputs or outcomes such as waste reduction, waste handling, managed waste, waste recycling, and recycling rates. Optimization of budget allocation for waste reduction at the source The Bappeda of Semarang City should allocate a more proportional budget for waste reduction at the source (reduce and reuse), such as programs to strengthen waste banks, household composting programs, and the development of 3R waste collection facilities. This strategy has proven to be more cost-efficient but has a significant impact on increasing the recycling rate. Strengthening waste system infrastructure through a decentralized processing system Given that the Jatibarang landfill is already overloaded, it is necessary to develop circular economy-based waste management infrastructure. Investments in waste management infrastructure must take into account long-term waste generation projections and prioritize a minimization approach through a decentralized system or the strengthening of a management system that is carried out in a distributed or local manner close to the source of waste generation rather than centralized in one large location such as the TPA (Final Disposal Site). This system aims to reduce the burden on landfills and improve the overall efficiency of waste management, such as 3R waste collection points, waste banks, and the provision of composting facilities for households and communities. In this case, the DLH is responsible for technical planning and operational supervision, while the Disperkim integrates it into the settlement and public space planning.

Provision of Incentives and Implementation of extended producer responsibility (EPR). The DLH, in collaboration with the Badan Pendapatan Daerah Kota Semarang (Regional Revenue Agency), implements an incentive program for entrepreneurs in restaurants, hotels, food stalls, cafes, malls, and others who apply the concept of extended producer responsibility (EPR), meaning that entrepreneurs are responsible for the collection, processing, and recycling of products or packaging they produce after they are used by consumers. This aims to reduce waste, especially from single-use packaging, food waste, and non-recyclable equipment. This policy can be strengthened by providing fiscal and non-fiscal incentives, such as tax reductions for restaurants, hotels, malls, and others, as well as awards for environmentally friendly businesses. Conducting regular performance evaluations based on output and outcome. The Regional Development Planning Agency (Bappeda) and the Environmental Agency (DLH) of Semarang City should conduct regular data-based evaluations of the implementation of the waste management budget allocation. This evaluation should focus on cost-effectiveness, input-output efficiency, and the success of environmental indicators such as waste reduction, waste management, managed waste, waste recycling, and recycling rates.. Strengthening Cooperation with Multiple Parties for Efficiency and Sustainability

The Semarang City Government needs to continue to encourage synergy with various sectors such as the private sector, communities, academics, and universities in waste management programs. This collaboration can improve performance in waste management, such as developing recycling business models, working with the community to develop waste sorting systems, and integrating corporate social responsibility (CSR) programs for the environmental sector. Development of Technology and Digitalization in Waste Management. The DLH is working with the Semarang City Communication, Information, Statistics, and Coding Agency to develop information technology to improve the operational efficiency of waste management, such as waste reporting systems, GPS-based waste transportation, and the use of sensors at collection points, as well as the development of systems that accommodate suggestions or innovations from various parties for the Semarang City Government. Development of Waste Management Financing Schemes. This financing is developed through optimized cooperation with the private sector through Public-Private Partnerships, the use of corporate CSR funds for waste management programs, and access to special allocation funds from the Ministry of Environment for waste management programs. This approach can expand the regional fiscal

space, so that the allocation of the regional budget for waste management can be maximized. Strengthening Regulations and Law Enforcement. The Semarang City Development Planning Agency (Bappeda) prioritizes waste management programs by synchronizing waste management policies in planning documents such as the RPJMD and RKPD and imposing strict sanctions on violators who dispose of waste illegally. Improving Environmental Education and Awareness The DLH collaborates with the Education Agency to include local curricula or extracurricular activities on waste management, or to hold inter-school waste recycling competitions. It conducts community-based campaigns such as encouraging RT/RW, PKK, youth organizations, and communities to hold regular training on waste sorting and processing. It utilizes social media and digital technology such as educational content on Instagram, TikTok, YouTube, Facebook, etc. Involve business actors and public figures, such as inviting cafe, restaurant, and food stall owners to display educational messages on how to sort waste. Provide education through rewards, such as giving prizes to households that actively sort waste.

The policy recommendation emphasizes that waste management in Semarang City must be directed towards a circular economy and fiscal efficiency paradigm with the support of cross-sector coordination. The Environment Agency is the leading sector in technical implementation, with the support of Bappeda as the planning coordinator, as well as active collaboration from all regional apparatus, the private sector, academics, and the community. The implementation of integrated, data-driven, and results-oriented policies is key to realizing sustainable waste management that is adaptive to urban development challenges.

## Conclusion

The results of this study show that the budget allocation for waste management for 2021–2024 fluctuates, increasing in 2022 but decreasing in 2023 and 2024. Although the budget allocation in 2023 and 2024 has decreased, waste management performance has actually shown an improving trend. The 2024 DEA analysis results show that 2024 is the most effective year with a score of 1.00 and 2022 is the least efficient year (score of 0.73). The CEA analysis shows that 2024 is the most effective year and 2022 is the least effective year, with the cost per ton of waste reduction falling from IDR 859,692/ton in 2022 to IDR 575,229/ton in 2024, the cost per ton of managed waste in 2022 was Rp227,184/ton, decreasing to Rp160,747/ton in 2024, and the cost per ton of waste recycling was Rp3,340,078/ton in 2021, decreasing to Rp587,554/ton in 2024. The results of the Pearson correlation test show that there is no significant relationship between the amount of budget allocation and the variable of waste management performance. Therefore, to improve effective, efficient, and sustainable waste management, the following steps can be consistently implemented in Semarang City: the application of a performance-based budget for the environment, optimization of budget use, strengthening of waste infrastructure through a decentralized system, providing incentives and implementing the concept of extended producer responsibility (EPR) for entrepreneurs, conducting regular performance evaluations based on output and outcome, strengthening regulations and law enforcement, providing rewards to communities or households that actively sort waste, and increasing community participation.

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