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ANALYSIS OF SUSTAINABLE COMMUNITY-BASED WASTE MANAGEMENT POLICIES IN THE CITY OF WAIKABUBAK

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Abstract

Waste management in Waikabubak City continues to face various challenges, including increasing waste generation, limited infrastructure, inadequate technology, and low community participation, resulting in suboptimal environmental sustainability. This study aims to analyze the sustainability status of community-based waste management policies and evaluate the operational effectiveness of the existing waste management system. A mixed-methods approach with a descriptive-analytical design was employed. Sustainability was assessed using the Rapid Appraisal for Waste (RapWaste) approach based on Multi-Dimensional Scaling (MDS), while operational effectiveness was evaluated using the Overall Equipment Effectiveness (OEE) method. Primary data were collected through observations, interviews, questionnaires, and focus group discussions, supplemented by secondary data from government reports and policy documents. The results indicate that the overall sustainability index reached 46.21, classifying waste management in Waikabubak City as less sustainable. The institutional dimension achieved the highest score (56.59), whereas the technology dimension recorded the lowest (25.27), highlighting technology as the main priority for improvement. Furthermore, the OEE value of 21.587% indicates that operational effectiveness remains low despite a high availability rate (96.15%), primarily due to limited performance and poor waste processing quality. These findings imply that sustainable waste management requires integrated policy interventions focusing on technological innovation, infrastructure improvement, stronger institutional capacity, community participation, and the implementation of circular economy principles to achieve environmentally sustainable waste management.

Keywords: community-based waste management; multidimensional scaling; overall equipment effectiveness; sustainability; waste management policy.

INTRODUCTION (TNR, 12 BOLD)

Environmental degradation is a shared concern that must be addressed in all its complexity in various cities across Indonesia, including Waikabubak City in West Sumba Regency. The demographic dividend—which has the potential to boost economic activity through an expanded labor force, increased income, higher consumer spending, and *changing* lifestyles—has a direct impact on the rising volume of waste generated. Such situations and conditions pose a serious obstacle when not accompanied by *environmental good governance*—specifically, effective, participatory, and sustainable waste management (Santosa & Quina, 2014) .

To date, the waste management system in Waikabubak City has remained conventional. The West Sumba Regency Environmental Agency operates on a *"business as usual"* basis, employing a "collect, transport, and dispose" approach that relies on the Waikabubak City Final Disposal Site (TPA) as a last resort(Suharto, 2023) . The landfill system used is *a controlled landfill*, where waste is buried and spread using *an excavator*, followed by weekly backfilling with soil from the surrounding area. Nevertheless, the landfill still operates as *an open dump*, and this continues to pose environmental problems such as increasing waste generation, greenhouse gas emissions, potential groundwater contamination, and land constraints. These conditions indicate the need for a more comprehensive and integrated policy strategy(Klundert & Anschütz, 2001) .

Policy strategies for waste management mechanisms should not be merely technical in nature, but should also take into account the aspect of community participation. Through a *bottom-up* approach, the community is positioned as the primary actor in waste management, from the stages of collection, containment, sorting, reduction, to reuse by applying the 3R principles *(reduce, reuse, recycle),* so that the community develops a sense of responsibility and ownership toward the jointly agreed-upon program activities. This aligns with the perspective of sustainable development, which emphasizes the involvement of all multi-helix stakeholders, including the government, the private sector, the business community, academia, and the community (Sayed, 2015; D. Wilson, 2015). An analysis of community-based waste management policies in Waikabubak City is essential because it can illustrate the effectiveness of existing policies, the obstacles to their implementation, and the potential for *resilience* through more participatory and sustainable management strategies. Using a policy analysis approach, this study aims to evaluate current waste management policies, identify disparities between regulations and on-the-ground practices, and provide evidence-based policy recommendations (Darniyus et al., 2025).

Through this study, waste management in Waikabubak City is examined not only from the technical aspect of processing at *the controlled landfill* but also from sociocultural, institutional, ecological, economic, technological, infrastructural, and environmental perspectives, with reference to public policy. Thus, it is hoped that the results of this study will contribute to strengthening a sustainable and participatory waste management model that is in line with the local characteristics of the West Sumba community (Ministry of Environment Regulation No. 13 of 2012).

MATERIALS AND METHOD

Research Type

This study employed a mixed-methods approach, with a primary descriptive-analytical methodology. Quantitative analysis was conducted using Rapwaste—an adaptation of RAPFISH (Rapid Appraisal for Fisheries) based on Multi-Dimensional Scaling (MDS)—to assess the sustainability of waste management in Waikabubak City from various dimensions. Meanwhile, qualitative data were collected through in-depth interviews, observations, and questionnaires, and then analyzed using the Overall Equipment Effectiveness (OEE) concept to assess the operational effectiveness of waste management at the study site.

Scope of the Study

The scope of the study covers waste management in Waikabubak City, encompassing several dimensions, namely sociocultural, ecological, institutional, economic, technological, infrastructural, and environmental dimensions. The scope also takes into account the perceptions of stakeholders and the community surrounding Waikabubak City.

Research Location and Timeframe

The research was conducted in the Waikabubak City District due to its strategic role as a destination for nature and cultural tourism. The study was conducted from October through December 2025.

Population and Sample

The population included the following stakeholders: informants (40 people), former heads of the West Sumba Regency Environmental Agency, council members, business owners, waste pickers, employees of the West Sumba Regency Environmental Agency, residents of the Waikabubak City area, the Waikabubak City Subdistrict Head, and village heads and village secretaries throughout the Waikabubak City Subdistrict. The sample for the sustainability analysis was selected using purposive sampling,

Data Sources

1. Primary data: interviews, observations, questionnaires, and focus group discussions (FGDs)
2. Secondary data: government agency reports, policy documents, and relevant literature.

Data Collection Techniques

Conducted through field observations, interviews, questionnaires, RAPFISH-based FGDs, and documentation.

Data Analysis Techniques

1. Community participation was analyzed using quantitative descriptive methods based on a participation index. Data were collected from questionnaires, interviews, and focus group discussions (FGDs). Quantitative descriptive analysis using the participation index involved calculating the lowest, highest, and average scores, and determining categories (low, moderate, high) based on a Likert scale (1–5).
2. Sustainability was analyzed using the multidimensional RAPFISH technique, which includes: (1) attribute scoring for each dimension, (2) ordination and stress values using RAPFISH software (MS Excel), (3) attribute rotation to determine good/bad conditions, (4) leverage analysis to determine attribute sensitivity, (5) Monte Carlo analysis to account for uncertainty, The results are presented as a sustainability index across four

categories: unsustainable (0.00–25.00), less sustainable (>25.01–50.00), moderate (>50.01–75.00), and sustainable (>75.01–100.00).

Operational effectiveness is analyzed using OEE, based on predefined performance categories, including: (1) availability: the percentage of effective operational time; (2) performance: actual output compared to the target; (3) quality: waste that meets quality standards (recycled, not turned into residue); and (4) OEE results are categorized as: low (<50%), adequate (50–70%), good (70–85%), and very good (≥85% / world class).

RESULTS AND DISCUSSION

Overall, waste management sustainability in Waikabubak City falls into the "less sustainable" category, with a sustainability index of 46.21. Of the seven dimensions analyzed using RAPFISH, the institutional dimension recorded the highest score (56.59). The institutional dimension has an MDS index of 56.59 percent and a Monte Carlo index of 56.23 percent, with a difference of 0.37. This value indicates a fairly sustainable status, making the institutional dimension relatively stronger than the other dimensions. This suggests that rules, coordination, and the roles of institutions are already in place, although there is still a need to strengthen policy implementation and consistency. A stronger institutional framework typically serves as the primary driver for other dimensions, particularly the economic, technological, and infrastructure dimensions. If the institutional framework can effectively manage the division of roles, funding, and oversight, improvements in other dimensions will be easier to achieve. Therefore, the institutional dimension can be viewed as a critical fulcrum in the sustainability strategy(Bursamin et al., 2018).

The socio-cultural dimension is less sustainable (48.97) due to a lack of community involvement from the initial planning stage; thus, participatory expertise—meaning the use of the community's existing competencies—can facilitate internal training starting with families and enable them to solve problems independently. Equally noteworthy is the " " (material/financial) participation, which involves contributing funds, equipment, or materials—this constitutes an investment in working capital that ultimately yields *revenue sharing* (Pratama, 2023).

The infrastructure dimension (47.74) is considered less sustainable because it received an MDS index of 47.74 percent and a Monte Carlo index of 47.37 percent, with a difference of 0.37. This value places it in the "less sustainable" category. This means that the availability and quality of waste management facilities and infrastructure are still insufficient to support an effective and efficient system(Hikmah et al., 2017).

Environmental Dimension (47.72) The environmental dimension has an MDS index of 46.72 percent and a Monte Carlo index of 46.38 percent, with a difference of 0.34. This places the environmental dimension in the "less sustainable" category. This condition indicates that the impact of waste management on environmental quality still needs improvement, particularly regarding cleanliness, pollution, and waste residue reduction (Ministry of Environment/BPLH, 2025) regarding Presidential Regulation No. 109/2025

The environmental dimension is heavily influenced by social behavior, technological capabilities, and infrastructure support. If these three elements are weak, environmental quality will remain in a vulnerable state. Therefore, discussions on this dimension should emphasize that environmental sustainability is the result of the integration of all dimensions, not a standalone concept (Syafri et al., 2025).

Ecological Dimension (46.28) The ecological dimension received an MDS index of 46.59 percent and a Monte Carlo index of 46.28 percent, with a difference of 0.23. Its status is "less sustainable," meaning that ecological conditions are still not good enough to support a sustainable waste management system. This is typically related to the continued generation of waste, low rates of waste sorting, and impacts on the quality of the surrounding environment (Firdausi, 2024). Analytically, the ecological dimension is closely related to the environmental and technological dimensions. If waste treatment technology is underdeveloped and infrastructure is limited, ecological pressure will remain high. Therefore, ecological improvement cannot be achieved through a technical approach alone but must be accompanied by behavioral changes and institutional strengthening(Kholil et al., 2015).

The economic dimension shows an MDS index of 45.99% and a Monte Carlo index of 45.59%, with a difference of 0.40. These results place the economic dimension in the "less sustainable" category. This means that aspects such as financing, incentives, the value of waste, and economic efficiency are not yet strong enough to sustain the waste management system in the long term(El Kifaf et al., 2023). This situation indicates that waste management has not yet fully become an activity that generates tangible economic benefits for both the community and the operators. In fact, the economic dimension is crucial for operational sustainability, as without funding support and benefit schemes, programs can easily falter. Therefore, strengthening the circular economy, waste banks, and community incentives is essential (RISTIANA, 2026). Technology Dimension The technology dimension has an MDS index of 25.27 percent and a Monte Carlo index of 25.88 percent, with a difference of 0.16. This means the technology dimension falls into the "less sustainable" category and is even one of the weakest dimensions. These values indicate that the facilities, equipment, processing methods, and application of waste management technology remain very limited (SITI HERAWATI, 2023).

The low technology score has direct implications for the effectiveness of waste management in the field. Without adequate technology, the sorting, transportation, processing, and utilization of waste are difficult to carry out efficiently. Therefore, the technology dimension must be a priority for improvement because it is closely related to ecology, infrastructure, and the economy (Cendrakasih, 2021). The sociocultural and institutional dimensions serve as key supporting factors for sustainability. This success is achieved thanks to stakeholder support and community engagement, accompanied by outreach activities that reach various age groups and genders. Consistent education also fosters a new awareness among the public to sort and process waste at home(Ramang et al., 2023).

However, the technological and economic dimensions remain weak points. The lack of innovation in recycling products, the absence of service diversification, and low economic incentives reduce the public's motivation to increase the frequency of waste drop-offs(Asteria & Heruman, 2016; Hairuddin et al., 2026). These results can be seen in the leverage results for the sociocultural and institutional dimensions in the figure below:

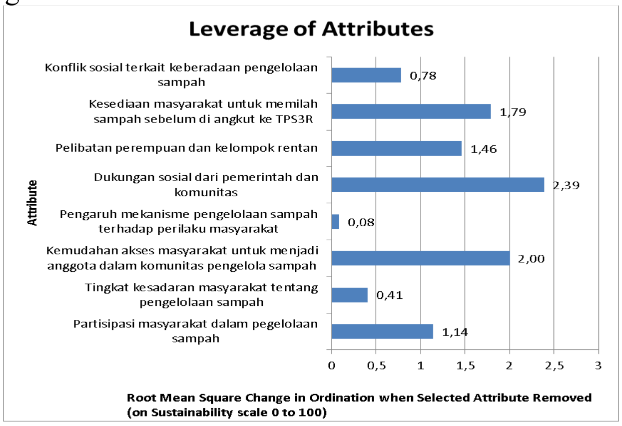

Figure 1. Sensitivity of Each Attribute in the Sociocultural Dimension

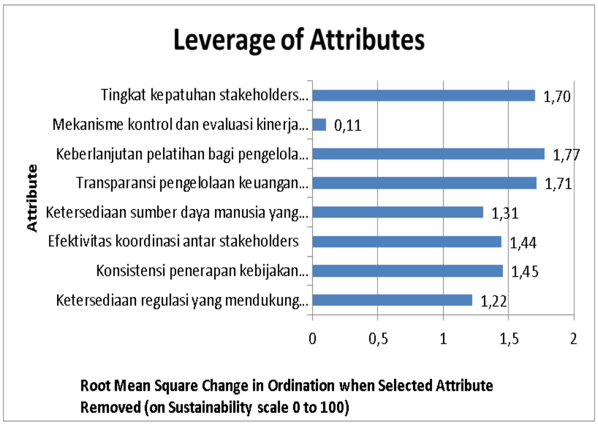

Figure 2. Sensitivity of Each Attribute in the

The institutional framework for evaluating waste management performance in Waikabubak City is crucial to ensuring the effectiveness of sustainable waste management activities. *Overall Equipment Effectiveness (OEE)* can be used to measure the success of operational activities across three main aspects, namely:

1. A*vailability*,
2. Performance, and
3. Quality.

This method is typically used in the machinery industry but can be applied to measure the effectiveness of waste management systems. In this study, the waste collection service provided by the available fleet operates only 4 hours daily, from 6:00 AM to 10:00 AM. The data used to calculate the OEE in this study comes from the West Sumba Regency Environmental Agency for the year 2024.

Availability is used to measure the extent to which the operational time of the Waikabubak City waste collection fleet is actually utilized as planned, without disruptions or cancellations. These disruptions can include delays by the “yellow squad,” staff absences, lack of equipment, bad weather, national holidays, or other technical issues. According to an adaptation from (Laksono & Wahyu, 2023), the mathematical formula is adjusted as follows:

$$\text{Availability} = \frac{\text{Waktu Operasional yang Sebenarnya}}{\text{Waktu yang Direncanakan}} x100\%$$

Data
1. Planned schedule: 52 weeks × 24 hours = 1,248 hours/year
2. Actual Realization: 50 weeks = 50 × 24 hours = 1,200 hours/year
   Availability $= \frac{1.200}{1.248}$ × 100% = 0.962 = 96.15%

Based on the calculations, *the* operational *availability of* Waikabubak City’s waste collection fleet reached only 96 percent, with an actual number of operating hours of 1,200 out of a target of 1,248 hours per year. This indicates that although the fleet was planned to operate every week for a full year, in practice, waste collection only operated for about 50 weeks a year—or 24 hours a week—with an average of just 4 effective working hours per day for the “yellow squad” (sanitation workers). Limitations in the waste collection fleet and the high cost of spare parts, coupled with budget efficiency policies, have resulted in suboptimal operational performance of the sanitation workers and the fleet. This has a significant impact on the level of community participation in urban waste management (Kaza et al., 2018; D. C. Wilson et al., 2013). This situation is also reflected in the sociocultural dimension, where the public’s willingness to sort waste before it is transported to the TPS3R remains very low—a critical issue with a high leverage value—indicating that the success and sustainability of waste management in Waikabubak City heavily depend on the provision of adequate waste infrastructure in every sub-district or at the local RT/RW level(Kaza et al., 2018).

Performance calculations based on the 2024 waste intake target, according to data from the West Sumba Regency Environmental Agency:

Dump truck = 2 trips × 3 units × 6 m^3/unit × 0.8 × 365 days
= 10,512 m^3/year
Arm roll = 2 trips × 3 units × 6 m^3× 0.8 × 365 days
= 10.512
Three-Wheeled Motorcycle = 2 trips × 6 units × 2 m^3/unit × 0.8 × 365 days
= 7.008 m^3/year
Total 28.032 m^3 /year

To convert 28,032 m^3/year to metric tons, multiply the volume by the density (specific gravity) of the waste in the truck’s body. The density of waste in a truck typically ranges from 0.3 to 0.4 metric tons per cubic meter because it undergoes natural compaction when thrown or dumped into the truck bed. The density commonly used in Indonesia is 0.3 $^{\text{metric tons per cubic meter}}$.

Therefore, 28,032 × 0.3 = 8,409.3 metric tons per year.

Even at 28,032 $^{m^3}$per year, this figure still exceeds the domestic waste generated by a population of 16,903 people (± 15,000 $^{m^3}$); the difference comes from waste generated by markets, shops, the city center, and offices. If the community processes 20–30% of their household waste at the source, the number of waste collection trips—whether by *dump trucks, arm roll trucks,* or even three-wheeled motorcycles—can be reduced from two trips to one, which can save on operational costs for fuel and *maintenance* costs for waste collection vehicle parts.

The volume of waste transported in the city of Waikabubak was determined using the *Load Count Analysis* method, which involves counting the number of vehicle loads entering the Final Processing Site (TPA). Given the limitations of the weighbridge, a correction factor of 0.8 was applied. SNI 19-3964-1994.

Data:
1. Target: 28,032 m^3/year
2. Actual Realization = 20,971 $^{m^3}$in 2024
3. Number of weeks in 2024: 52 weeks in 1 year
4. Number of weeks based on 2024 data: 50 weeks per year / actual.
   Therefore, the annual target is 28,032 m^3per year

Performance $= \frac{Reaksi\ Aktual}{Target\ tahunan} x100\%$

Performance = $\frac{20.971}{28.032} x 100\% = 0{,}748 = 74{,}81\%$

The calculation results show that *the performance of* the operational waste management fleet during 2024 reached only 74.81%, amounting to 20,971 m^3 of waste collected out of the annual target of 28,032 m^3.

The quality of waste management reflects the extent to which waste is successfully sorted and selected through collection by informal waste pickers and channeled to waste collectors, thereby reducing the burden on landfills. This assessment is important because it demonstrates the effectiveness of sustainable waste management. The higher the proportion of waste that is successfully managed, the better the quality of waste management services in supporting a clean environment. The "Quality" value in this study is estimated at 30% based on waste management conditions that are still dominated by open burning (± 70%) and low rates of transport to official facilities. This ± 30% estimate aligns with the range of quality values reported in the literature for suboptimal management systems, which typically fall around 30%. This literature-based estimate was chosen because waste management systems in developing regions still have relatively low success rates, with waste often being incinerated or disposed of indiscriminately, as explained by the World Bank (2016) and the Ministry of Environment and Forestry. Therefore, the low quality score indicates that most waste is not yet properly managed, making it the primary factor contributing to the low overall OEE score.

Data:

The calculation of waste management quality in Waikabubak City shows a low result of 30%, with a total of 20,971 m^3. This OEE calculation is performed by multiplying the three main indicators calculated previously, namely:

OEE (%) = *Availability* (%) × *Performance* (%) × Quality (%)

Data:
Availability = 96.15%
Performance = 74.81%
Quality = 30.00%

Therefore:
OEE (%) = 0.962 × 0.748 × 0.300
= 0.2158
= 21.587%

The OEE (*Overall Equipment Effectiveness*) calculation results for the analysis of sustainable community-based waste management policies in Waikabubak City, at 21.587%, indicate that the overall operational effectiveness of waste management remains low, primarily due to *performance* (74.81%) and *availability* (96.15%). The *Quality* score of 30% reflects that actual productive working time is still not optimal because the amount of managed waste is smaller than the amount of unmanaged waste (Pramesti et al., 2025).

CONCLUSION

Community-based waste management in Waikabubak City, based on the RAPFISH analysis, shows a sustainability index of 46.21, placing it in the "less sustainable" category. The institutional dimension is the best-performing aspect (56.59) and falls within the "moderately sustainable" category, while the technological dimension is the weakest (25.27), followed by the economic, ecological, environmental, infrastructure, and socio-cultural dimensions, which remain in the "less sustainable" category. An analysis of operational effectiveness using the Overall Equipment Effectiveness (OEE) method yielded a value of 21.59%, indicating that the waste management system is still ineffective. This low effectiveness is primarily influenced by limitations in processing technology, poor waste management quality, inadequate facilities and infrastructure, and suboptimal community participation in the implementation of the 3R principles.

Based on these findings, there is a need to strengthen more integrated waste management policies by enhancing institutional capacity, providing adequate waste management technology and infrastructure, developing a circular economy through waste banks and the utilization of recycled materials, and increasing community participation through education and collaboration with various stakeholders. These efforts are expected to improve the operational effectiveness of waste management while promoting the realization of a sustainable waste management system in Waikabubak City.

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