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Analysis of Waste Processing Technology on Community Willingness to Pay in Madiun City Using the Analytic Hierarchy Process (Case Study: Waste Processing at TPA Winongo, Madiun City)

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ABSTRACT

The objective of this study is to explore stakeholder perspectives on the prioritization of waste treatment technologies in Madiun City and to estimate the community's Willingness to Pay (WTP) for improved waste management services. This research utilized both primary and secondary data. Primary data for the Analytic Hierarchy Process (AHP) method were collected through 30 respondents using the Expert Choice application, targeting stakeholders involved in the waste management sector. Meanwhile, the WTP estimation was based on purposively sampled responses from 100 individuals—50 respondents from Manguharjo sub-district and 50 from Manisrejo sub-district. The results of the AHP analysis indicate that the highest priority waste treatment technology in Madiun City is controlled landfill, with a weight of 0.39, followed by composting at 0.36, and waste segregation at 0.25. The criteria and alternative evaluations were deemed consistent, as indicated by a Consistency Ratio (CR) of ≤ 0.1. In terms of WTP, the amount the community is willing to pay for the segregation method is relatively low, at less than IDR 2,000. This contrasts with the composting method, where respondents are willing to pay more than IDR 2,000, and the highest WTP is observed for the controlled landfill method, exceeding IDR 3,000. The variation in WTP values is also influenced by demographic factors such as gender and occupation.

KEYWORDS *Waste Treatment Methods, AHP, WTP*

INTRODUCTION

Waste is a very important problem in our lives (Gupta et al., 2022). Every day we produce waste, so if we do not process waste properly, it will cause problems (Kaza et al., 2018). In addition, the increasing population in Madiun City, reaching 202,544 people, is also one of the triggers for the increase in waste generation (Central Statistics Agency, 2024). According to the Law of the Republic of Indonesia Number 10 of 2008 concerning Waste Management, waste is defined as the residue of human daily activities and/or natural processes in solid form (Ministry of Environment, 2008). The generation of solid waste cannot be stopped but must be properly managed, reduced, or minimized (Ferronato & Torretta, 2019). Financing in waste management must be effectively handled by the Regional Government (Pemda) because, in general, waste management requires large costs, especially for operational engineering costs from collection, transportation, and management to the final disposal site (Gattringer et al., 2020). The city of Madiun produces around 120 tons of waste every day; this amount can increase on weekends or certain periods. For example, during the Eid holiday, the increase in waste generation can reach 300 tons per day due to the large number of travelers (Kusumawati et al., 2021). According to the Madiun City Environment Agency, around 85.98 tons of waste enter the landfill per day, around 4.3 tons are sorted and processed organic waste, and 8.56 tons are sorted and processed inorganic waste (Putri & Rahman, 2020 ; Edi Hartono, 2006).

According to (Surjandari et al., 2009), the increase in the number of people accompanied by an increase in the amount of waste will affect the amount of waste that must be sorted to make the processing process easier, both based on the type of waste (organic and inorganic waste) and its benefits (for recycling, composting, and so on) (Sharma & Chattopadhyay, 2022). As an alternative, recycling processing utilizes inorganic waste, and this process only delays or prevents inorganic waste materials from accumulating in landfills (Abdel-Shafy & Mansour, 2018). Meanwhile, compost utilizes organic waste and is able to reduce waste by 62.5% of the total organic and inorganic waste (Nair et al., 2021). Waste segregation itself has been proven to significantly enhance recycling efficiency and reduce environmental burdens (Ferronato et al., 2021). Composting is also considered one of the most effective biological treatments for organic waste, improving soil quality and reducing methane emissions from landfills (Boldrin et al., 2019). Therefore, proper sorting and processing methods remain essential components within municipal solid waste management systems (Yadav et al., 2020).

The city of Madiun, in waste management using the collection-throw-transport system, is currently running well. This method can reduce the generation of waste scattered in each Temporary Disposal Site (TPS). However, the limited landfill land makes the existing waste increase, disturbing the environment and causing an unpleasant odor. Waste management data per sub-district in Madiun City can be seen in the table below:

Table 1. Data on waste management in Madiun City

District	Population	Total generation	Waste reduction	
	RT	Tons/ Year	Tons/ Year	%
Manguharjo	15.000	15.053	474	3,1%
Taman	21.507	21.584	988	4,6%
Kartoharjo	13.868	13.916	377	2,7%
Sum	**50.365**	**50.543**	**1839**	**3,6%**

Source: Results of the analysis of the PKP working group, 2022

Based on Table 1, the least waste reduction in Madiun City is in Kartoharjo sub-district, which is 2.7% of the total waste generation. Waste reduction is carried out by selection through waste banks. Almost every village in Madiun City has formed a waste bank with the aim of sorting existing household waste before it is disposed of at the Temporary Disposal Site (TPS). Data from the Madiun City Environment Agency shows that until 2023, there are 168 waste bank units, but only 83 units, or around 49.4%, are still actively operating (Table 2).

Table 2. Active waste bank data per sub-district

District	Number of registered waste banks	Number of active waste banks	Percentage
Manguharjo	50	25	0,15%
Taman	60	30	0,18%
Kartoharjo	58	28	0,16%
Sum	**168**	**83**	**0,49%**

Source : Environment Agency in 2023

According to (Millati Haqq, 2018), in IKPLHD, 2016, the waste bank is a collective inorganic waste management system that encourages the community to play an active role in sorting waste and also making handicrafts from waste, thereby increasing the selling value and having a positive impact on the environment, social, and economic conditions for the communities involved (Józwik et al., 2018; Mikhalieva et al., 2016). The inactivity of the role of waste banks will result in an increase in waste generation from each polling station. In this case, solving the waste problem requires good cooperation between all parties involved. The waste management paradigm must also be based on the concept of waste management that supports the principles of sustainable and environmentally sound development. The role of the government as a regulator must be able to address the problem of waste properly and correctly.

According to Chamdra et al. (2005), the limitation of waste management facilities and infrastructure results in a low level of waste management services. This is related to financing issues. Based on the Regulation of the Mayor of Madiun No. 11 of 2017 concerning the Levy for Waste/Cleaning Services, the amount of the levy rate for residential houses, category 3, is only Rp. 1,000, with the provision that houses on the roadside with a road width of 1 (one) to 7 (seven) meters (Madiun City Government, 2017). It is hoped that the determination of the levy rate, by paying attention to the willingness to pay of the community in Madiun City, will increase income from waste management, which is expected to balance the cost of improving waste services in Madiun City.

Regarding the waste problem at the Winongo Landfill in Madiun City, the local government needs to find alternative waste processing technology. This alternative is expected to make it easier for the Madiun City Government to obtain a waste management policy that not only minimizes the accumulation of waste but also considers various aspects, namely technical, economic, social, and environmental. This research aims to identify the most appropriate waste processing technology that can be effectively implemented to reduce waste generation at the Winongo Final Processing Site (TPA). Specifically, this study seeks to: (1) determine the priority ranking of waste treatment technologies (sorting, composting, and controlled landfill) using the Analytic Hierarchy Process (AHP) method based on technical, economic, social, and environmental criteria; (2) estimate the community's Willingness to Pay (WTP) for each waste treatment alternative; and (3) analyze the factors influencing community acceptance and payment capacity for improved waste management services.

The benefits of this research are multifaceted. Theoretically, this study contributes to the body of knowledge on multi-criteria decision-making in municipal solid waste management, particularly in developing country contexts where resource constraints and community participation are critical factors. Practically, the findings provide actionable recommendations for the Madiun City Government and the Environmental Agency in formulating evidence-based waste management policies that align with both technical feasibility and community capacity. The results can serve as a reference model for other municipalities facing similar waste management challenges. Furthermore, this research offers insights into the relationship between waste treatment technologies and community financial willingness, which is essential for designing sustainable and economically viable waste management systems. For policymakers, this study provides data-driven evidence to support the development of appropriate levy structures and incentive mechanisms that balance service improvement needs with community affordability.

METHOD

This study employs a mixed-method research design, combining qualitative and quantitative approaches to comprehensively examine waste processing technology preferences and community willingness to pay in Madiun City. The research was conducted at the Winongo Final Processing Site (TPA), Madiun City, East Java, Indonesia, from March to August 2024.

The population of this study consists of two distinct groups. For the AHP analysis, the population includes all stakeholders involved in waste management decision-making in Madiun City, comprising government officials from the Environmental Agency, waste bank coordinators, and community leaders. For the WTP analysis, the population encompasses all households in Manguharjo and Manisrejo sub-districts.

Sampling for the AHP component utilized purposive sampling technique, selecting 30 expert respondents based on their expertise and involvement in waste management. These respondents included 10 officials from the Madiun City Environmental Agency, 10 waste bank coordinators from various districts, and 10 community leaders representing different neighborhoods. The selection criteria ensured that respondents possessed adequate knowledge and experience in waste management practices. For the WTP component, purposive sampling was also employed, with a total of 100 household respondents—50 from Manguharjo sub-district (which is located near the Winongo Landfill) and 50 from Manisrejo sub-district (which is located 10.2 km away from the landfill). This geographical distribution was deliberately chosen to capture variations in community perspectives based on proximity to the landfill facility, thereby minimizing response bias and ensuring data validity.

Data collection techniques involved both primary and secondary data sources. Primary data were obtained through structured questionnaires and semi-structured interviews. For the AHP analysis, expert respondents completed pairwise comparison questionnaires evaluating four criteria (technical, economic, social, and environmental) and three alternatives (sorting, composting, and controlled landfill). For the WTP analysis, household respondents were first provided with detailed hypothetical scenarios describing each waste treatment method, including its advantages and disadvantages, before being asked about their willingness to pay additional levies for improved services. Secondary data were obtained from the Madiun City Central Statistics Agency (BPS), the Environmental Service (DLH), Manguharjo Village Office, and Manisrejo Village Office, including demographic data, waste generation statistics, and existing waste management performance indicators.

Data analysis techniques consisted of two main methods. First, the Analytical Hierarchy Process (AHP) was employed to determine the priority ranking of waste treatment technologies. AHP, developed by Thomas L. Saaty (1980), is a structured technique for organizing and analyzing complex decisions based on mathematics and psychology. The AHP hierarchy in this study consists of three levels: the goal (determining optimal waste processing technology), criteria (technical, economic, social, environmental), and alternatives (sorting, composting, controlled landfill). Data were processed using Expert Choice software to calculate criterion weights, alternative priorities, and consistency ratios (CR). A CR value of ≤ 0.1 indicates acceptable consistency in judgments. Second, Willingness to Pay (WTP) analysis was conducted to estimate the monetary value that community members are willing to contribute for improved waste management services. WTP analysis employed the Contingent

Valuation Method (CVM), which assesses the value of non-market goods by directly asking people their willingness to pay for specific services or environmental improvements (Mitchell & Carson, 1989). Descriptive statistics were used to analyze WTP distributions across different demographic groups and treatment alternatives. The integration of AHP and WTP methodologies provides a comprehensive framework for evaluating both technical prioritization and economic feasibility of waste management interventions.

RESULT AND DISCUSSION

Pairing comparison and weighting criteria

The results of paired comparison and weighting criteria from the AHP hierarchical structure above are shown in **Table 3** and the output of the graph in **Figure 2**. The Weight and *Consistency Ratio* (CR) for the comparison matrix between the criteria has a CR value of 0.05. This indicates that the criterion matrix is considered consistent because the CR value is < 0.1. The order of weight of the highest criteria starts from engineering (55%), then economic (26%), social (13%) and finally environment (6%). From the results of weighting, this criterion will be used to calculate the priority scale of each waste management alternative.

Table 3. Weights and CR values for paired comparison matrices between criteria

Criterion	Weight
Technique	0,55
Economics	0,26
Social	0,13
Milieu	0,06
CR (*Consistency Ratio*)	0.05 < 0.10

Figure 2. Output graph of the results of the analysis of the paired comparison matrix between the criteria

The percentage of engineering criteria of 55% reflects that the community is more likely to prioritize operational reliability that can be adjusted to the conditions of the Winongo Landfill. This is natural considering the limited capacity of infrastructure, the condition of the land topography and the generation of waste which is getting higher day by day. The separation of technically superior technologies is believed to be faster in responding to management crises than economic, social and environmental-based approaches. The economic criterion meets the second order, which is 26% because there is a tendency for people to have solutions with measurable values, for example processing smapah into compost. Meanwhile, the weight of social (13%) and environmental (6%) criteria is low, indicating a lack of community participation in the surrounding waste and community behavior that does not care about the environmental impact caused by waste generation.

1. Determination of alternative stages of waste treatment technology

The determination of alternative rankings from each criterion is used to determine the appropriate waste processing technology used at the Winongo Landfill in Madiun City. Based on the data processing that has been carried out, it can be seen that each alternative weight of the criteria can be seen in the table and figure below:

Table 4. Alternative weighting of technical criteria

Alternatif	Weight	Percent
Sorting	0,194	19,4
Composting	0,325	32,5
Controll landfill	0,480	48,0

Figure 3. Alternative analysis output graph to the technical criteria

Table 5. Alternative weights of economic criteria

Alternatif	Weight	Percent
Sorting	0,398	39,8
Composting	0,434	43,3
Controll landfill	0,168	16,8

Figure 4. Output graph of alternative analysis to economic criteria

Table 6. Alternative weights of social criteria

Alternatif	Weight	Percent
Sorting	0,197	19,7
Composting	0,355	35,5
Controll landfill	0,447	44,7

Figure 5. Output graph of alternative analysis to social criteria

Table 7. Alternative weights of environmental criteria

Alternatif	Weight	Percent
Sorting	0,117	11,7
Composting	0,273	27,3
Controll landfill	0,609	60,9

Figure 6. Alternative analysis output graph to environmental criteria

Based on Table 4, the highest alternative weight of the engineering criteria is landfill control, which is 48%, then composting is 32.5% and sorting is 19.4%. An alternative analysis output graph to the technical criteria can be seen in Figure 3. In the technical criteria, landfill control has the highest percentage weight because it is considered to reduce waste piles and is easy to apply the technology. Meanwhile, sorting has the lowest weight because it is less able to significantly reduce waste generation.

The alternative weight of the economic criteria in Table 5 is the highest is composting, which is 43.3%, then sorting 39.8% and landfill control 16.8%. An alternative analysis output graph to the technical criteria can be seen in Figure 4. Composting alternatives on economic criteria have the highest weight because of low capital and operational costs. Meanwhile, the landfill control has the lowest weight because economically waste processing requires a lot of money. The alternative weight of social criteria in Table 6 is the highest landfill control, which is 44.7%, composting 35.5% and sorting 19.7%. An output graph of alternative analysis to social criteria can be seen in Figure 5. In social criteria, landfill control has the highest alternative weight because it can provide and absorb a considerable amount of labor. In addition, the leachate produced can provide benefits in the form of methane gas for underprivileged residents. The methane gas produced can be used by them as a substitute for LPG gas. The weight of the alternative sorting on social criteria has the lowest percentage due to the lack of empowerment and community participation in the selection of waste in each village that has a waste bank.

Meanwhile, the alternative weight of environmental criteria in Table 7 is the highest landfill control at 60.9%, then composting is 27.3% and sorting is 11.7%. An alternative analysis output graph to the technical criteria can be seen in Figure 6. The alternative weight of the landfill control has the highest percentage because a lot of organic waste in the Winongo Landfill can be processed to produce methane gas. Meanwhile, the alternative weight of sorting has the lowest percentage because the sorting process is considered less effective in reducing the generation of waste in landfills. From the table and graph image above, it can be seen that the weight and Consistency Ratio (CR) for the comparison matrix between alternatives are considered consistent because the CR value < 0.1.

Prioritization of waste management technology

The determination of the priority ranking of waste processing technology at the Winongo Landfill in Madiun City can be seen in the table below:

Table 8. The order of priority scale of waste processing technology at the Winongo Landfill, Madiun City

Alternatif	Weight Technical	Economic Weight	Weight Social	Environmental Weight	Priority Scale
	0.55	**0,26**	**0,13**	**0,06**	
Sorting	0,194	0,398	0,197	0,117	0 ,25
Composting	0,325	0,434	0,355	0,273	0,36
Controll landfill	0,480	0,168	0,447	0.609	0,39

Source : Field survey results

Based on Table 8, the priority scale of waste processing technology with the highest AHP method is 0.39% landfill control, then 0.36% composting, and 0.25% sorting from 30 (thirty) respondents. This shows that community participation in waste processing problems is very high.

Waste handling with a landfill control system or landfill with soil is less effective due to the condition of the landfill that is full or full capacity so that the waste management carried out does not run as it should and there is still a lack of existing facilities and infrastructure and then the budget limitations that are owned (Congge et al., 2023). is considered to have a more controlled social impact than other methods because the location of the Winongo Landfill is relatively far from dense residential areas, and methane gas has been handled through limited piping for the needs of surrounding households. However, in the field, it shows that the Winongo Landfill is overcapacity with an accumulation of waste reaching 30 meters and without infrastructure improvements, groundwater pollution, greenhouse gas emissions, and the potential for landslides in landfills will occur.

The composting method obtained the highest score on economic criteria (43.3%) and was second overall (0.36%). This is in line with the characteristics of the composition of waste in Madiun City, where more than 50% of the waste produced is organic waste. This makes composting the most materially suitable method to be developed, both on a centralized scale at the Winongo Landfill and at the community level (waste bank). From an economic point of view, composting is considered to have added value because it can produce fertilizer products that have selling value. However, the success of this method depends largely on the quality of the sorting. The exsisting condition of the landfill shows that the waste received is generally in a mixed condition, so composting cannot be carried out directly without an initial separation process. Furthermore, the limited operational area at the Winongo Landfill is a challenge because composting requires open space and a long process time. Thus, composting has great potential, but its success requires the support of the upstream sorting system and the active role of the community as well as the expansion of technical facilities.

The sorting got the lowest score overall (0.25%) and on all dimensions except economics. This reflects the reality on the ground, where the sorting system in Madiun City is still partial and not integrated. Although waste banks have been established in almost all urban villages, the volume of waste that has been successfully reduced is only 3.6% of the total generated (DLH, 2022). The main obstacles to sorting are low community participation and limited local recycling markets. On the other hand, sorting has a long-term positive impact because it supports strategies of reduction from source and advanced processing efficiency. Therefore, while sorting is not a top priority in the short term, strengthening education and its supporting infrastructure is essential to improve the effectiveness of other technologies such as composting and recycling.

The value of the community's WTP to waste management technology

In determining the Willingness *To Pay* (WTP) value, it was carried out using 100 respondents who were taken by *purposive sampling.* The sample was divided into 2, namely 50 respondents in Manguharjo village and 50 respondents in Manisrejo village. According to (Nainggolan, 2019) in (Han et al., 2019: 173) the study, people had a much higher willingness to pay than they did and was positively correlated with their participation in waste collection, willingness to sort waste, willingness to send waste, and willingness to dispose of waste. Various factors, public awareness of the need for waste management are closely related to the awareness and socio-economic factors of the community. From the results of the study, it is known that there are as many as 28 respondents (28%) who are not willing to pay the WTP value while 72 respondents (72%) are willing to pay. This shows that community participation to increase regional levies for waste management is very high. To find out the WTP value, it is necessary to make the following hypothetical scenario:

Table 9. Scenario of waste processing technology at the Winongo Landfill, Madiun City

Scenario 1	: Sorting	Namely waste processing which aims to separate plastic and non-plastic waste. . The advantages of this system are that it does not cause pollution, low costs but has the weakness of waste will accumulate.
Scenario 2	: Composting	Namely waste processing which aims to utilize organic waste into compost. The advantage of this system is that it can produce added value because compost fertilizer can be sold, but the disadvantage of this system is that it is only limited to organic waste so that inorganic waste remains that must be processed with other systems
Scenario 3	: *Control Landfill*	That is, waste processing by spreading garbage until it reaches a certain thickness and then compacted using heavy equipment such as a bulldozer to then be coated with soil and recompacted. At the top of the soil pile, garbage can be spread again which is then piled up again with soil. Continue until layers of garbage and soil are formed. The advantages of this system are low investment and operational costs, and the methane gas generated can be used by residents as a substitute for LPG gas. The disadvantage of this method is that it requires a large location.

Hypothetical scenario in Table 9. aims to give an overview to the community when they want to give a certain amount of their money for improving waste processing in Madiun City. The willingness to pay the WTP value is greatly influenced by several factors, including gender, age, education, occupation, income, number of family members and the length of time you live at home. Based on the results of interviews with respondents, the composition data on alternative waste processing WTP was obtained as follows:

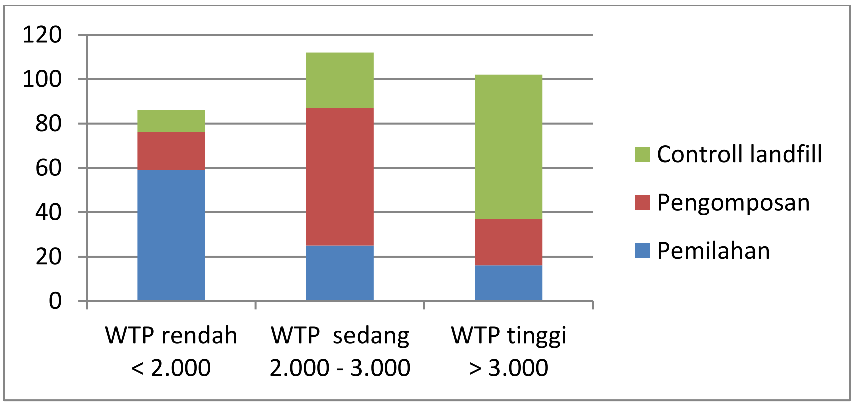

Figure 7. Composition of respondents to alternative waste management WTP

Based on Figure 7. that the respondent chose an alternative to waste processing with the sorting method, the money willing to be paid by the respondent was relatively smaller, which was less than Rp. 2,000,- when compared to the composting method of more than Rp. 2,000,- and the highest was the control landfill method with a value of more than Rp.3,000,-. This shows that the higher the technology used, the higher the money that will be paid by the community and vice versa.

There was a big difference in the WTP value chosen by respondents for male sex than for females. This could be because the majority of male respondents are the head of household and/or who have their own income. Meanwhile, female respondents received more money from their husbands (Sulistya Rini Pratiwi, 2019). The amount of WTP paid by the community for waste processing at the Winongo Landfill in Madiun City is also influenced by gender and employment factors.

CONCLUSION

The data processing using the Analytic Hierarchy Process (AHP) showed that the priority waste processing technology at Winongo Landfill, Madiun City, is the controlled landfill method with a score weight of 0.39, followed by composting at 0.36 and sorting at 0.25, based on responses from 30 sampled participants. The community's willingness to pay (WTP) is highest for the controlled landfill method at Rp. 3,000, followed by composting at over Rp. 2,000, with sorting being the lowest at less than Rp. 2,000. Additionally, factors such as gender and employment significantly influence the size of the community's WTP. Future research could explore a larger and more diverse sample size to examine other socio-demographic factors affecting WTP and assess the long-term sustainability and community acceptance of these waste processing methods.

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