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Research Paper

# Multi-Attribute Utility Theory Decision Analysis for Biodegradable River Debris Composting Treatment in Surakarta City

Mega Mutiara Sari[1]*, Takanobu Inoue[2], Regil Kentaurus Harryes[3], Kuriko Yokota[2], Iva Yenis Septiariva[4], Sapta Suhardono[5], Shigeru Kato[2], Suprihanto Notodarmojo[6], Aninda Putri Nafisah[1], I Wayan Koko Suryawan[1]

[1]*Department of Environmental Engineering, Faculty of Infrastructure Planning, Universitas Pertamina, Jakarta, 12220, Indonesia*
[2]*Department of Architecture and Civil Engineering, Toyohashi University of Technology, Toyohashi, 441-8580, Japan*
[3]*Faculty of Vocational Studies, Universitas Pertahanan Indonesia, Bogor, 16810, Indonesia*
[4]*Department of Civil Engineering, Faculty of Engineering, Universitas Sebelas Maret, Surakarta, 57126, Indonesia*
[5]*Department of Environmental Science, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret, Surakarta, 57128, Indonesia*
[6]*Department of Environmental Engineering, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Bandung, 40132, Indonesia*
***Corresponding author e-mail**: mega.ms@universitaspertamina.ac.id

**Abstract**
River waste in Surakarta City primarily consists of biodegradable waste that can be processed by biological processes such as composting. However, there are various kinds of composting application techniques. This, of course, must be adapted to the conditions in Surakarta City. This study aims to conduct a decision analysis on debris processing techniques in Surakarta City using the Multi-Attribute Utility Theory (MAUT) method. The criteria used are aesthetics, land requirements, ease of operation, ease of construction, and investment and operational costs. Alternatives used in composting are bamboo aerator system, hollow brick, and takakura arranges. The final assessment by MAUT showed that waste processing with hollow brick (0.802) had the highest weight and was followed by the bamboo aerator system (0.643). The final score for the takakura method is only 0.250, and this is because the weight on costs and land requirements is considerable compared to the other two alternatives.

**Keywords**
Debris, Composting, MAUT, Decision Analysis

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## 1. INTRODUCTION

Marine debris is a persistent solid object, produced or processed by humans, directly or indirectly, intentionally or unintentionally, dumped or left in the marine environment (Pawar et al., 2016; Iñiguez et al., 2016; Gall and Thompson, 2015). Marine debris causes many problems, which affect the aesthetic condition of the sea, ecosystems, and biota, and worst of all, it impacts human health (Gallo et al., 2018; Purba et al., 2021; Septiariva et al., 2022). The debris composition in several studies shows that the type obtained with biodegradable waste types such as leaves and tree branches has the highest percentage (Sari et al., 2022). This includes the river area in the City of Surakarta. People's daily activities include caring for and cleaning plants by pruning them. The waste resulting from pruning and cleaning the plant is disposed of in the drainage channel. The organic waste results based on the age of use of organic materials can still be used in making compost (Sayara et al., 2020).

In addition to plant residues, another type added to composting is animal manure. The nutrient composition of each animal's excrement is different depending on the amount and type of food. In general, the nutrient content in animal manure is much lower than in chemical fertilizers, so the dose of their use will also be higher (Mackie et al., 1998). Nutrients are available for a long time to not easily be lost in the environment (Sarwono et al., 2022; Suryawan et al., 2021a; Vembrio et al., 2020; Suryawan et al., 2021b). Besides beneficial nutrients, manure also contains saprophytic bacteria, disease carriers, and parasitic microorganisms that can harm animals or humans. Although compost does not contain as many macro elements as artificial fertilizers, this fertilizer contains more microelements needed by plants. Compost is excellent to use as an organic fertilizer because, with the addition of this organic fertilizer, the soil structure can be improved (Naveed et al., 2014), increasing the capacity of the soil to bind water and increasing the binding capacity of the ground to nutrients so that they are not readily soluble in water.

Composting can be done on a large scale or household (Pandyaswargo and Premakumara, 2014). Household scale composting uses a unique drum designed to accommodate household waste using the composting method. The advantages of household-scale composting are that it does not require a large land area, does not produce a disturbing odor, is easy to do, and is better compost quality. However, it is necessary to avoid including eggshells, meat, and bones in composting because it will slow down the composting process and cause a bad smell. Several composters are embedded composters, composters with an aerator, takakura composters, and without an aerator.

The community is an essential element that will affect the success of waste management. The community's interest in managing waste starting from themselves will be reflected in many who object to being asked to make compost. However, for the good of sorting waste at home, some respondents stated that they were willing and not willing. On the other hand, most respondents were willing to do waste sorting. In addition, community interest in waste management is reflected in their willingness to participate in waste bank activities in recycling their inorganic waste. However, most respondents have a low willingness to make organic waste processing into compost. Therefore, composting processing is not better done in a centralized manner with various available technology options (Zurbrügg et al., 2005).

Because of the many technologies that can be chosen, decision analysis is needed to select the right one. Multi-Attribute Utility Theory (MAUT) is a method of decision-making. MAUT is a method to find the weighted number of the same values for each utility on each attribute (Van Calker et al., 2006; Ozdagoglu and Çirkin, 2019). This method can also process data from all attributes with different utilities. Therefore, the MAUT method can also assist in making decisions in choosing a composting technology based on the many different attributes. The MAUT method also has many advantages: the performance rating on each attribute (cost and benefit) does not need to be normalized. This research aims to provide a decision analysis on the strategy of resolving biodegradable waste to be processed with composing technology for debris in Surakarta City.

## 2. EXPERIMENTAL SECTION

### 2.1 Materials

This research was conducted by direct observation technique. In addition, data collection is also carried out by direct documentation. The results of the observations were then analyzed under ideal conditions based on the literature study. To support the research, this study was also conducted on the composition of degradable waste by measuring the generation and composition of biodegradable waste. This research was conducted in a tributary area of the Bengawan Solo river, namely the Tanggul river (Figure 1). The study was carried out from January to June 2021.

### 2.2 Methods

To determine the waste management that can be carried out, it should be implemented at the study site. By finding the weight value for each attribute or aspect of the assessment in composting, a final value is optimized for problems in existing conditions. Decision analysis can produce good waste management by ranking. Previous research has implemented the MAUT method in determining environmental planning and maintenance, especially waste management (Sari et al., 2022b; Sari et al., 2022c; Sari et al., 2022c; Hilmi et al., 2022). Each alternative has a utility value on each of its criteria. The utility value will be normalized to produce an evaluation value. From the evaluation value obtained, it is obtained the accuracy of the results so that the evaluation value of each alternative can be taken as a decision.

## 3. RESULTS AND DISCUSSION

The decision is an activity of choosing a strategy or action in problem-solving. In decision making, data and information processing need to be done to produce alternative decisions that can be taken. So, decision-making must be based on logical considerations to be accepted by all parties who target the decision. For that, we need a system that can help produce decisions. Therefore, the decision-making system is designed to support all decision-making stages, from identifying problems, selecting relevant data, determining the approach used in the decision-making process, and evaluating choices. This study has determined three alternatives, as shown in Figure 2.

Based on the 2017 TPS 3R Technical Guidelines, there are three alternatives for organic waste processing: bamboo aerator, hollow brick, and takakura. Some of the criteria that need to be considered in determining the composting method based on the Minister of Public Works Regulation Number 3 of 2013 Menteri Pekerjaan Umum Republik Indonesia (2013) and the 2017 TPS 3R Technical Guidelines Direktorat Pengembangan PLP (2011) are as follows:

1. Aesthetics: related to the arrangement of the waste processing room. In addition, one of the factors that are the focus of waste processing (Marshall and Farahbakhsh, 2013).
2. Land requirement: related to how much land area is needed for processing. This is important because the land requirement for each area is limited, and composting is a waste processing process that requires quite a lot of space. The calculation of land requirements for the four alternatives follows the 2017 TPS 3R Technical Guidelines by the Ministry of PUPR (Direktorat Pengembangan PLP, 2011).
3. Ease of operation is based on the worker's ability, the level of knowledge, the number of stages of work to be carried out, and the complexity of the tool. Although work that requires skills to bring satisfaction will affect performance

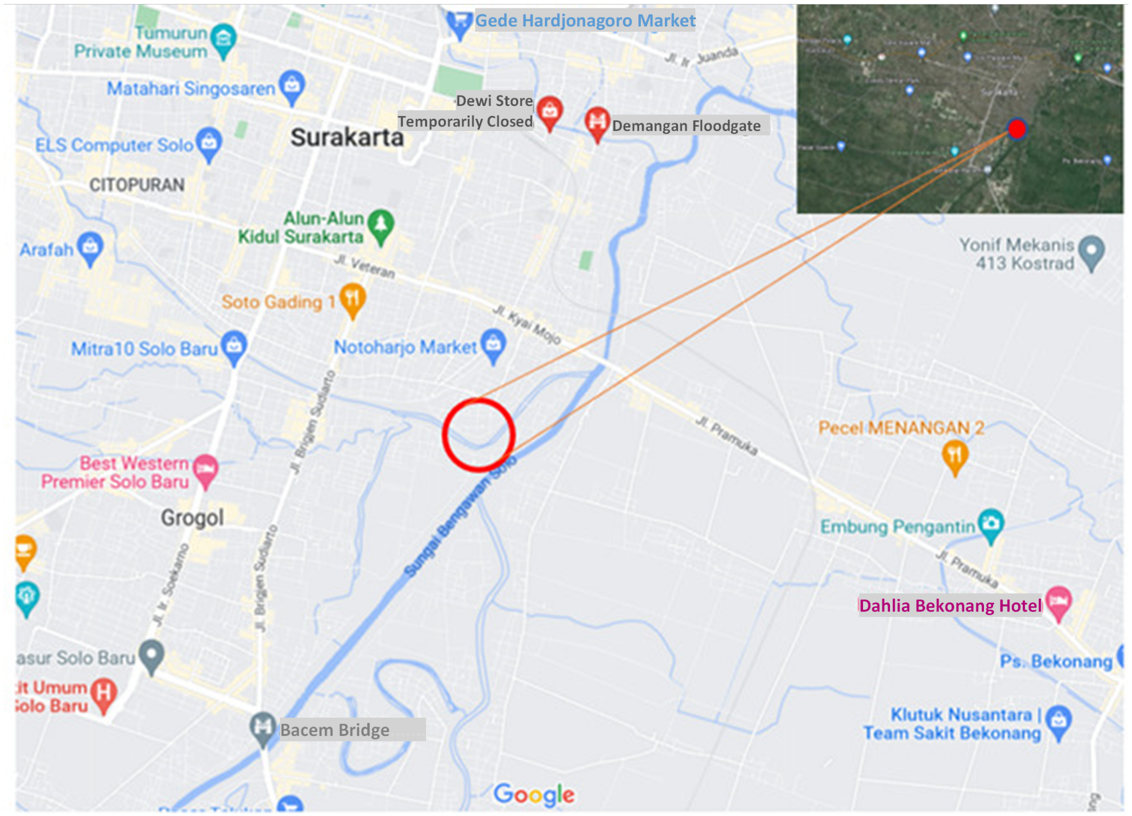


**Figure 1.** Study Location

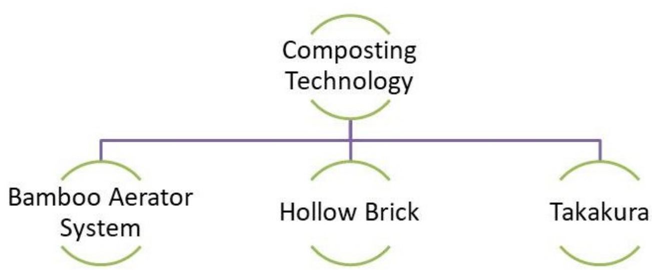


**Figure 2.** Altervative Composting Technologies for Biodegradable Debris in Surakarta City

(Marshall and Farahbakhsh, 2013), if working is done based on composting skills, good employee performance may be created, which also creates good organizational productivity.
4. Ease of construction knows the ease of getting composting tools and materials on the market and how to implement them in the field. However, the more difficult it is to get tools and materials, it will affect the work volume and time will increase the workload of the workers.
5. Investment and operational costs: knowing the description of expenses that must be needed at the beginning as a form of investment and expenses for processing operations. The reference in determining the costs incurred refers to the market price in Surakarta City.

Alternative 1: bamboo aerator system, this technique is done by making a triangular bamboo construction with longitudinal slats installed on both sides of the triangle and then backfilling it with organic waste. Initially, organic waste was chopped with a chopping machine. The organic waste is then stockpiled in the bamboo aerator unit. The organic waste that has been composted is then sieved using a sieve machine. The compost is packaged and stored in the compost storage room (Bertha et al., 2021). Oxygen will flow between the cavities. The composting process uses a tool in a bamboo aerator assisted with EM4 as an additional material to speed up the biological degradation process (Lestari, 2021; Suryawan et al., 2021c; Ulhasanah et al., 2022). The need for land for the bamboo aerator compost can be seen in Table 1.

Alternative 2: hollow brick, composting using the hollow brick technique is done by stockpiling organic waste in boxes made of hollow bricks. This technique uses cavities in the walls and vertical pipes in a pile to circulate air during the composting process. At the base of this brick arrangement, a hole serves to collect water from the pile of garbage. According to the Minister of Public Works Regulation Number 3 of 2013 (Menteri Pekerjaan Umum Republik Indonesia, 2013), organic waste is piled up in boxes with a height of one layer of 20 cm every day and

**Table 1.** Calculation of Land Requirements for Bamboo Aerator Sytem

| Parameters | Symbol | Equation | Value | Unit |
|---|---|---|---|---|
| **Design Criteria** | | | | |
| Composting time | t | | 30 | day |
| Height | Hmaks | | 1.75 | m |
| **Planning Data** | | | | |
| Compost volume | Vk | | 2.3 | $m^3$/day |
| Waste volume in time t | Vt | Vk x t | 69 | $m^3$ |
| **Compost Calculation** | | | | |
| Long | p | | 6 | m |
| Bottom width | Lb | | 3 | m |
| Top width | La | | 2 | m |
| Tall | T | | 1.5 | m |
| Cross area | $A_l$ | (Lb x La)/2 x T | 3.75 | $m^2$ |
| Compost volume | $Vk_1$ | $A_l$ x length | 22.5 | $m^3$ |
| Aerators needed | n | $Vt/Vk_1$ | | unit |
| Wide side turning space | Pl | | 0.5 | m |
| Long side reversal space | Pp | | 1 | m |
| The area of each bamboo aerator | a | (Lb x Pl) x (p + Pp) | 24.5 | $m^2$ |
| Composting total area | A | n x a | 75 | $m^2$ |

then composted for 30 days. After 30 days, the compost is removed to be aired for 15 days. Then the compost can be harvested and packaged. The need for hollow brick composting land can be seen in Table 2.

Alternative 3: takakura, composting with this method is done by piling the garbage in a basket that has a cavity. The baskets used can be made of plastic or wood. The cavity on the side of the basket serves to drain oxygen during the composting process. In contrast, the cavity at the bottom of the basket serves to drain excess water from the composting process. Before the waste is put into the basket, the basket is first covered with plastic and a sack on the outside. After that, the waste can be put in, and the baskets are stacked in five stacks. The composting process is carried out for 30 days and 15 days of maturation to be harvested and packaged. The need for land for takakura stacking composting can be seen in Table 3.

From the assessment results and weighting using the utility theory method, the alternative with the highest ranking is alternative 2. This indicates that alternative 2 is a better alternative to be applied to the processing of aquatic organic waste. In terms of land area, land area is the primary consideration in choosing waste processing technology because of limited land in existing conditions. Therefore, land area has the essential weight, namely 1. Calculation of land area requirements for the composting area for each alternative refers to the Minister of Public Works Regulation Number 3 of 2013. Alternative 3 has the largest composting area because it requires a lot of baskets for composting. In addition, investment costs will affect the design of the cost budget. The greater the investment cost of composting technology, the greater the design budget required. Therefore, this parameter is given a weight of 3.

The hollow brick method has difficulty with ease of construction because it requires a long process and time in brick and pipe construction. Meanwhile, bamboo aerators and takakura stacking have easy development because they are essential processing tools and are available in the market. Therefore, the parameter of ease of development is not as crucial as the parameter of land area, investment, and operational costs, so it weight 2.

In terms of aesthetics, alternative 2 has the lowest value because the composting process tends to be in an open space without any containers as in other methods, so the compost pile can be scattered by the wind. On the other hand, according to the Minister of Public Works Regulation Number 3 of 2013, the hollow brick method of composting looks neat, structured, sturdy, and strong because it is supported by a brick construction design that looks neat.

In terms of operational convenience, based on the Minister of Public Works Regulation Number 3 of 2013, the bamboo aerator method requires regular monitoring and discipline so that the level of operational ease is moderate. On the other hand, the hollow brick method does not require a long operating time and easy monitoring. Meanwhile, takakura requires complex monitoring because it has to check each box and requires a lot of human resources.

Composting waste will always cause odors, even in very good composting conditions (D'Imporzano et al., 2008). However, different composting methods can have an effect. For example, hollow brick boxes will still cause an odor. However, it will not smell too bad due to a large amount of oxygen intake from the brick cavity and the low water content due to the vertical pipe in the box when compared to

 

**Table 2.** Calculation of Land Requirements for Hollow Brick

| Parameters | Symbol | Equation | Value | Unit |
|---|---|---|---|---|
| **Planning Data** | | | | |
| Composting time | t | | 30 | day |
| Crib height | T | | 1.2 | m |
| Crib length | P | | 6 | m |
| Crib width | L | | 4 | m |
| Compost volume | Vk | %organik x V | 2.3 | $m^3$/day |
| Waste volume in time t | Vt | Vk x t | 69 | $m^3$ |
| **Box Calculation** | | | | |
| Box volume | V | P x L x T | 28.8 | $m^3$ |
| Pipe height | Tp | | 0.2 | m |
| Net box volume | Vb | P x L x (T-Tp) | 24 | $m^3$ |
| Number of boxes | n | Vt/Vb | 3 | unit |
| **Space Calculation** | | | | |
| Masonry length | Pb | | 6 | m |
| Long side space | Rp | $A_l$ x length | 0.4 | m |
| Width of masonry | Lb | | 0.1 | m |
| Wide side space | Rl | | 0.3 | m |
| Total length | $P_{tot}$ | P + (2 x Pb) + (2 x Rp) | 7.2 | m |
| Total width | $L_{tot}$ | L + (2 x Lb) + (2 x Rl) | 4.8 | m |
| Area per unit | a | $P_{tot}$ x $L_{tot}$ | 35 | $m^2$ |
| Composting room | A | n x a | 105 | $m^2$ |

**Table 3.** Calculation of Land Requirements for Takakura

| Parameters | Symbol | Equation | Value | Unit |
|---|---|---|---|---|
| **Planning Data** | | | | |
| Composting time | t | | 30 | day |
| Compost volume | Vk | | 2.3 | $m^3$/day |
| Waste volume in time t | Vt | Vk x t | 69 | $m^3$ |
| **Number of Takakura** | | | | |
| Long | P | P x L x T | 0.6 | m |
| Wide | L | | 0.3 | m |
| Tall | H | P x L x (T-Tp) | 0.43 | m |
| Seat height | td | | 0.8 | m |
| Quantity per stack | n | | 5 | unit |
| Takakura volume | $V_{tk}$ | P x L x H | 0.0774 | $m^3$ |
| Compost pile volume | v | P x L x (H-td) | 0.06 | $m^3$ |
| Number of takakura | | Vt/v | 1150 | unit |
| Number of stacks | nt | Number takakura/n | 230 | unit |
| **Space Calculation** | | | | |
| The distance between the ends of the takakura | s | | 0.4 | m |
| Length per unit | Pp | $A_l$ x length | 1.8 | m |
| Takakura unit width | Lp | | 1.3 | m |
| One unit compost room | Pp x Lp | | 2.34 | m |
| Composting room | $A_{tot}$ | $A_1$ x nt | 538.2 | $m^3$ |

the open windrow method and bamboo aerators. In addition, there are only allowed to accumulate in the composting area and tend to be more prone to waterlogging or oxygen shortages (Jackson, 1979). The recapitulation of MAUT calculations can be seen in Table 4, Table 5, and Table 6.

Hollow bricks function to circulate air in the heap of waste through porous pipes. This construction circulates the air in the compost through holes in the walls and vertical

 

**Table 4.** Recapitulation and Assessment of Each Alternative

| Parameters | Alternative 1 | Alternative 2 | Alternative 3 | Weight |
|---|---|---|---|---|
| Land requirements | 171 | 242 | 1,193.4 | 3 |
| Investment cost | Rp. 600,000 | Rp. 7,500,000 | Rp. 41,400,000 | 3 |
| Ease of development | Easy | Difficult | Easy | 2 |
| Aesthetics | Not well organized | Very organized | Pretty organized | 3 |
| Ease of operation | Currently | Easy | Difficult | 2 |
| The ordour | Very smelly | Smells | No smell | 1 |

**Table 5.** Score Assessment and Scoring

| Parameters | Alternative 1 | Alternative 2 | Alternative 3 | Worst | Best |
|---|---|---|---|---|---|
| Land requirements | 171 | 242 | 1,193.4 | 1,193.4 | 171 |
| Investment cost | Rp. 600,000 | Rp. 7,500,000 | Rp. 41,400,000 | Rp. 41,400,000 | Rp. 600,000 |
| Ease of development | 3 | 1 | 3 | 1 | 3 |
| Aesthetics | 1 | 3 | 2 | 1 | 3 |
| Ease of operation | 2 | 3 | 1 | 1 | 3 |
| The ordour | 1 | 2 | 1 | 1 | 3 |

**Table 6.** Alternative Assessment Using Utility Theory

| Parameters | Alternative 1 | Alternative 2 | Alternative 3 | Weights | Standar weights |
|---|---|---|---|---|---|
| Land requirements | 1 | 0.931 | 0 | 3 | 0.1 |
| Investment cost | 1 | 0.934 | 0 | 3 | 0.1 |
| Ease of development | 1 | 0 | 1 | 2 | 0.2 |
| Aesthetics | 0 | 1 | 0.5 | 3 | 0.1 |
| Ease of operation | 0.5 | 1 | 0 | 2 | 0.2 |
| The ordour | 0 | 0.5 | 0 | 1 | 0.3 |
| Total | | | | 14 | 1 |
| Utility theory | 0.643 | 0.802 | 0.250 | | |
| Ranking | 2 | 1 | 3 | | |

pipes in a pile. While the holes between the pipes at the bottom are channels for water in the pile of garbage in the box. The use of hollow bricks is considered very appropriate because the water content of debris is very high (Wang et al., 2003). After all, it can interfere with the degradation process of microorganisms (Ulhasanah et al., 2022). Especially if two other alternatives are chosen, they can be eroded due to the high water content to the bamboo aerator and the takakura reactor.

Compost that has been packaged neatly and adequately will be stored in a safe compost storage container, and the place is also not damp. This is to avoid the emergence of mold that can damage the attractiveness of the packaging. The warehouse size is calculated based on the equivalence between the weight and volume of the compost that has been cooked. The compost storage warehouse building is equipped with a good and good ventilation system. A laboratory at the location is also needed to determine the quality of the compost produced.

Management and protection of the environment are the responsibility of the government, both central and local governments. For example, the impact of dumping garbage in rivers, such as being a nest of disease for residents living around the banks of the Bengawan Solo river, can be suppressed (Aulia and Triwahyudi, 2020). Breeding places for animals that bring sources of disease such as mosquitoes, rats, and waste that accumulate in rivers can also block the flow of river water so that it can cause flooding. Composting biodegradable waste can also greatly assist the government in reducing waste to landfills (Davis and Song, 2006; Sari et al., 2022).

## 4. CONCLUSIONS

The final evaluation of the MAUT showed that waste processing with hollow brick (0.802) had the highest weight and was followed by the bamboo aeration system (0.643). On the other hand, the final score for the takakura method is only 0.250, and this is because the weight in costs and land requirements is considerable compared to the other two alternatives. The application of waste processing utilizing composting should also be directed so that the waste can be managed properly to answer the problem of waste so far that has not been completely resolved, also directed at empowering local communities around Tanggul river.

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