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Research Article

Decision Analysis of the Composting Unit at Pluit Emplacement, Jakarta Using the Open Bin, Windrow, and Static Pile Methods for Biodegradable Waste

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Abstract
Indonesian marine debris of aquatic waste in Jakarta is managed by the UPK of the Water Agency, one of which is the Pluit Employment. Several composting methods can be used and adapted to the available circumstances and needs. The composting process is carried out by utilizing the supply of oxygen, nutrients, water, and temperature control. This study aims to analyze the selection of alternative composting systems that can be carried out for planning the composting unit at Pluit Employment. Selection analysis was carried out using the Utility Theory and Compromise program methods. Alternative 1: This alternative uses a composting system using an open bin. Alternative 2 uses a simple windrow system with garbage piled up without heavy equipment during operation. Alternative 3 uses a composting system with a static pile system with a machine turning it over. In the composting method chosen, alternative 2. The distance between compost for workers' movement space, it can reach 1 m as in the TPS 3R Technical instructions, that because it does not use machines, the land used for machine movement is reduced. Limited land can be utilized for the amount of windrow so that the amount of processed waste can be more significant.

Keywords: Debris; open bin; windrow; static pile; decision analysis

1. Introduction
In the 2018 synthesis report regarding Indonesian Marine Waste, the management of aquatic waste in Jakarta is managed by the UPK of the Water Agency. This management is carried out by

collecting waste found on the water's surface through currents. The collected waste will be transported by truck. The transportation is carried out from several points to emplacement locations (transfer stations). Debris collection system with devices such as garbage filter bars prevents various kinds of waste from escaping along the river, such as logs, animal weeds, and other debris (Sari et al., 2022b, 2022a). In addition to collecting waste in the waters, some facilities can be used such as standard excavators, garbage trucks, boat collection, garbage filter bars, and bamboo trash traps (World Bank, 2018).

A composting process produces compost with benefits as a material to help enrich the soil by improving the physical, chemical, and biological properties of the soil (Ayilara et al., 2020; Rombel et al., 2022). The many benefits of compost are one of the things that are recommended to support programs regarding Material Recovery Facilities (Christensen et al., 2020).

The reduction of biodegradable waste is primarily made in Indonesia using a composting system (Damanhuri et al., 2009). Composting is a method of processing organic waste by aerobic decomposition of organic material (Külcü and Yaldiz, 2014). The compost produced can be used in agricultural activities (Mehta and Sirari, 2018). The type of biodegradable waste that is often processed using the composting method is garden waste (Chen et al., 2019). However, composting has drawbacks, such as the compost produced has a low nutrient content and takes a long time to ripen. This is the reason why compost is rarely used.

Food scraps can be composted in a row or in a trash bin at an alternative one if space is available. This bin system can handle significant amounts of material. It also allows step-by-step composting, using one part for storing compostable materials, one part for active composting, and one part for pickling or finished compost. The second alternative uses a simple windrow system with garbage piled up. This method produces a product that is uniform and can be located remotely. However, converting compost can be labor intensive or require expensive equipment. In areas with high rainfall, compost can be piled above the soil surface and protected by shade. Piles are made with dimensions of 2.2mx 1.4mx 5m (width x height x length) (Sesay et al., 1997). The pile usually starts with a 20 cm thick layer of carbonaceous material such as leaves, straw, sawdust, wood chips, and chopped corn stalks. Then it is covered with 10 cm thick nitrogenous material such as fresh grass, weeds or garden plant residues, dung, or digested dung (fresh or dry) (Manna et al., 2015). The weakness of the windrow system is that it requires a large area. The static pile system has almost the same method as the second alternative but is given a perforated pipe for airflow. The air is pressed through the blower so that the pile of waste raw materials to be processed can be more than 1 meter. If the temperature is too high, the oxygen flow is temporarily stopped. When the temperature drops, oxygen is added (Svendsen et al., 2016). There is no reversal process, so the compost raw material must be made homogeneous from the start. There must be a large cavity in the mixture.

Several waste management methods can be adapted to the available circumstances and needs (Raksasat et al., 2021; Septiariva et al., 2022; Zahra et al., 2022). The composting process utilizes oxygen, nutrients, water, and temperature control. Composting with a windrow itself means composting by stacking the composted waste with dimensions and considering aspects such as temperature and period of reversal (Wahyono and Sahwan, 2016). Because the composting system can be applied to various kinds of debris, it is necessary to analyze the selection of the best alternative. Therefore, this study aims to analyze the choice of alternative composting systems that can be carried out for planning the composting unit at the Pluit Emplacement.

2. Method

Composting system using the windrow method, which can be used for planning the composting unit at Pluit Emplacement, was selected using the Utility Theory and Compromise program methods. This method is used to make decisions in the form of a strategy that is considered to solve the best solution so that you can know what to do (Hadinata, 2018). Utility theory, or what can be called

Multi-Attribute Utility Theory (MAUT), is an evaluation assessment by focusing on an object that is judged to represent a number relevant o its dimension value. The utility theory calculation method can use equation 1 (Hadinata, 2018).

$$U(x)\frac{(x-Xi)}{xi^{+}-xi^{-}} \tag{1}$$

The alternative sorting method used is the Utility Theory and Compromise Program method. Both ways are included in the Multi-Criteria Decision Making (MCDM), which is the method used in making a decision or selecting an alternative to be made or chosen as the best decision (Alinezhad and Khalili, 2019). After that, the utility (Vi) is multiplied by the standardized weight (Wi) to find the value or rating of each alternative.

$$V(x) = \sum_{i=1}^{n} Wi.Vi(x) \tag{2}$$

Following are the calculation steps used in determining the best alternative using the compromise program method (Yu, 1973). The first is that alternatives are broken down into parameters or components for evaluation. Then provide an assessment of the components of each alternative to obtain the object value of each alternative (zij). After that, we must convert an objective value (zij) to a relative value (nij). The relative value is dimensionless, so a 0-1 scale is used. Here's the formula for calculating relative values:

$$nij = \frac{z_{ij}-\min(z_{ij})}{\max(z_{ij})-\min(z_{ij})} \text{ ; i = 1,...,m; j = 1,...,n} \tag{3}$$

Then the weight value of each component is determined, so the more significant the weight value, the more important it is considered. After that, the weight of each component is divided by the total weight to get the standard weight (ai) for each component. Calculating relative distance with this formula :

$$dc_i = \left[\sum_{j=1}^{J} a_i \text{ x } (1 - n_{ij})^p\right]^{\frac{1}{p}} \text{ ; i = 1,...,m; j = 1,...,n} \tag{4}$$

Calculating indicator value:

$$I_{ij} = 1 - dc_i \text{ ; i = 1,...,m} \quad (5)$$

Finally, the alternative ranking assessment is selected based on the value closest to the number 1 so that the alternative is chosen.

3. Result and Discussion

The choice of this alternative focuses on the method and process of piling up to affect the operational processes, land, and monitoring conditions in the composting unit later. The composting process refers to the Material Recovery Facilities Technical Guide and the Integrated Waste Management (Damanhuri and Padmi, 2015). There are three alternatives given in this waste management: (Figure 1).

a. Alternative 1: This alternative uses a composting system using an open bin, such as one of the methods mentioned in the TPS 3R technical guide and Regulation of the Minister of Public Works no. 03 of 2013 (Kementerian Pekerjaan Umum dan Perumahan Rakyat Republik Indonesia, 2013). The system is used by forming a box that is made permanent in the form of a square or rectangle like an open tub, and the accumulation of garbage is carried out in the box. This system has less aeration because it is limited by the tub wall even though it has been given ventilation holes.

b. Alternative 2: This alternative uses a simple windrow system with garbage piled up without heavy equipment during operation, and the pile is made with a flexible shape. Besides, this alternative does not use a particular container to accumulate organic waste. In this method, an aerator can be used or without an aerator, depending on the size of the pile of waste to be formed. This method can be used on a large scale, and workers can do the reverse process conventionally.

c. Alternative 3: This alternative uses a machine to use a composting system with a static pile system with an invert. This composting process must use a mechanical turning machine, bulldozer, loader, or other heavy equipment to move the compost or stir the compost (Damanhuri and Padmi, 2015). The aeration process is carried out by moving the compost from the previous location. The aeration process is obtained from mixing and moving the compost, which is effective if it is done every day.

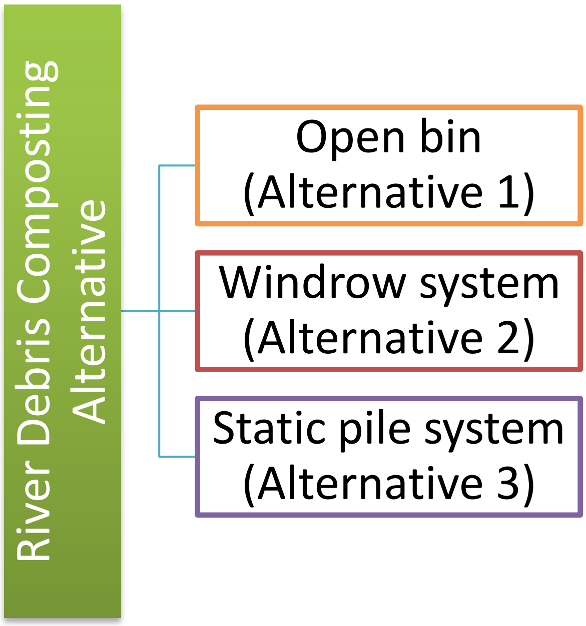

Figure 1. Composting alternatives for planning the composting unit at the Pluit Emplacement

Production facilities and operations on compost already need to pay attention to aspects of production. The tools and machines needed for production operations already exist, among others, detailed in Table 1. Tools that are damaged and lost and machines are damaged and often jammed, which can affect production activities (Brown et al., 2022). The following are the standards and criteria for weighting for selecting alternatives.

Table 1. Description of parameter assessment.

Num	Alternative Considerations	Score	Basis of Assessment
1	Distance between compost	0.1	Alternative 1 (m)*
		1	Alternative 2 (m)*
		5	Alternative 3 (m)**
2	Smell**	1	Easy to smell (high)
		2	Not easy to smell (medium)
		3	No odor at all (low)
3	Operation***	1	Not complex (low)
		2	Semi complex (medium)
		3	Complex (high)
4	Workload	1	Weight (height)
		2	Medium (medium)
		3	Light (low)
5	Fund	1,000,000	Alternative 1*

Num	Alternative Considerations	Score	Basis of Assessment
		200,000	Alternative 2*
		219,817,740	Alternative 3****
6	Reversal time	1	Frequency > 2 times per week (high)
		2	Frequency 1-2 times per week (moderate)
		3	Frequency 1 time per week (low)

Source: *(Kementrian PUPR, 2014) ** (Damanhuri and Padmi, 2015) *** (Kementerian Pekerjaan Umum dan Perumahan Rakyat Republik Indonesia, 2013) ****Prices are based on market survey results

To speed up the composting process, an activator or bio activator is needed and is generally added directly when mixing the raw materials to be decomposed. The term bio activator is defined as a microbial isolate that has been purified and has a special ability to digest organic materials containing cellulose fiber (Yuniwati and Padulemba, 2012). Some of the commonly used bio activators include EM-4 and effective microorganism 4. The EM-4 bio activator can accelerate the composting process and prevent odors during the composting process.

In applying household-scale composters, there are still many process failures caused by users not making adequate operational efforts. There are several requirements for the success of the composting process, including uniform waste size and temperature regulation. Meanwhile, many composter users are reluctant to cut the waste to make it uniform in size and turn the waste over so that the process temperature can be guaranteed. This mainly occurs in middle-high income communities, which contribute more to waste. With these considerations, it is deemed necessary to make a household scale composter that runs mechanically in cutting waste to a uniform size and turning the waste manually to reduce the failure of the composting process. In selecting alternatives, objective and subjective assessments were used in the composting process. The description of each assessment basis is attached in Table 2.

Table 2. Explanation of each value

Num	Alternative Considerations	Basis of Assessment	Explanation of Each Value
1	Distance between compost	Alternative 1	It takes minimal space between workers, and there is only a distance between compost boxes of up to 0.1 m.
		Alternative 2	It takes a distance between compost can reach 1m for workers' movement space
		Alternative 3	It takes a distance between compost of at least 5 m because it uses heavy equipment.
2	Smell	Easy to smell (high)	It is easy to smell because the aeration space is minimal.
		Not easy to smell (medium)	Not easy to smell because aeration is supplied either passively or routinely.
		No odor at all (low)	It doesn't smell at all because it's actively aerated.
3	Operation	Not complex (low)	It is not complex because the tools used are flexible and do not require more workers' training, and do not require additional experts.

Num	Alternative Considerations	Basis of Assessment	Explanation of Each Value
		Medium	Semi-complex because the lata used is not flexible, requires routine control of parts so that the tool does not easily clog, and cleaning is a bit complicated. Still, the training of workers does not require additional expertise.
		Complex (high)	Operation requires more expertise and training for workers because it requires machine operation and requires more maintenance or equipment maintenance.
4	Workload	Weight (high)	flexibility is limited so that it affects workers' tiny space so that large quantities of organic waste will require more time and more energy.
		Medium	the workload is moderate because the operation and control process is more flexible, and the workers have enough space to move, which helps to lighten the workload and speed up the work.
		Light (low)	low workload due to time in the process assisted by technology and expansive space for workers.
5	Fund	Alternative 1	box system price (open bin)
		Alternative 2	windrow price per unit
		Alternative 3	The price of one turning tool
6	Reversal time	Frequency > 2 times per week (high)	The reversal time is done every day because it avoids the anaerobic process.
		Frequency 2 times per week (medium)	Turning time can be done during a specific period in every week of the composting process with the help of a passive aeration process
		Frequency 1 time per week (low)	reversal time can be done once per week if assisted by the active aeration process.

Odor is based on factors caused if aeration does not go well. It will easily cause anaerobic conditions. Anaerobic conditions cause more odor than aerobic conditions (Suryawan et al., 2021). Operation refers to Permen PU No.03/PRT/M/2013, that managers' training needs to be carried out. The movement for the manager and the operator/mechanic will be different, so if the processing is more complex, the training and maintenance will also be more complex, and more skilled experts are needed. The workload received by workers is based on the flexibility of the composting system, adequate space for workers, and the technology used to assist with composting. So if in each alternative, it can be seen the workload received from the length of the operating process and the work volume from the ease in the work process that workers will receive from each alternative.

Table 3. Determination of criteria per method.

Parameter	Alternative 1	Alternative 2	Alternative 3
Distance between compost	0.1 m	1 m	5 m
Smell	High	Medium	Medium
Operation	Medium	Low	High

Parameter	Alternative 1	Alternative 2	Alternative 3
Workload	High	Medium	Medium
Tool costs in windrow fields	1,000,000	200,000	219,817,740
Reversal time	Medium	Medium	High

Turning time will affect the composting process and quality. Although composting with a time of reversal frequency will reduce the temperature significantly lower, if the pile is too humid, the composting process will be hampered because the water content that blocks the air cavity can affect the oxygen condition in a pile (Hutagaol, 2019). For this reason, an assessment of alternative composting is carried out based on Table 4.

Table 4. Determination of the best and worst values per method.

Parameter	Alternative 1	Alternative 2	Alternative 3	Worst value	The best value
Distance between compost	0.1	1	5	5	0.1
Smell	1	2	2	1	3
Operation	2	1	3	3	1
Workload	1	2	3	1	3
Fund	1,000,000	200,000	219,817,740	219,817,740	200,000
Reversal time	2	2	1	1	3

The weighting of each parameter is based on the urgency in composting concerning several factors that will affect the composting process, namely temperature, temperature, and pH, which can be affected by the aeration process (Yang et al., 2021). In addition, it is the amount of land required because the available land limits the design. The operation section is considered essential because the easier it is to operate, it will automatically affect the workload obtained by workers. The workload will follow the ease of operation in each method. Then odor monitoring is also considered necessary because it can signify that an anaerobic process is occurring. In addition, the odor that arises can interfere with activities around the composting unit, so its control can be done by controlling the temperature and water content factors with the given aeration process. The results of the standardization of weights for each alternative can be seen in Table 5.

Table 5. Weighting method per parameter.

Parameter	Alternative 1	Alternative 2	Alternative 3	Weight	Weight standard
Distance between compost	1	0.816	0	3	0.23
Smell	0	0.5	0.5	2	0.15
Operation	0.5	1	0	2	0.15
Workload	0	0.5	1	1	0.08
Fund	0.996	1	0	2	0.15
Reversal time	0.5	0.5	0	3	0.23
				13	

Alternative sorting that has become a relative value following equation 3-4. Then the determination of the amount of weight is carried out when each weight has been divided by the total weight to get the standard weight (Table 6), then uses the compromise program method by calculating the relative distance (Yu, 1973). After the indicator value is obtained, a value close to 1 is the best alternative that can be used.

Table 6. Rating value of each alternative

Parameter	Alternative 1	Alternative 2	Alternative 3
Utility Score	0.576	**0.727**	0.154
Rank	2	**1**	3
Compromise Program			
Compromise factor	2		
Relative distance	0.572	0.351	0.899
Indicator value	0.428	0.649	0.101
Rating	2	1	3

In the composting method chosen, alternative 2. Judging from the distance between compost for workers' movement space, it can reach 1 m as in the material recovery facilities. Technical instructions that the land used for machine movement is reduced because it does not use machines. Limited land can be utilized for the amount of windrow so that the amount of processed waste can be more significant. In addition, the windrow can use a passive aeration tunnel due to the high pile of garbage which is relatively high. Then because an aeration tunnel has accompanied it, it is reversed 1-2 times a week in composting. The temperature that arises in the composting process will not exceed 70°C, and the oxygen supply in a heap will not be less than 50%. Then the composting results can reach the standard of SNI 19-7030-2004 because of the availability of aeration aid. It can help evaporate the excess water content at the bottom of the compost and quickly help reduce the temperature in the compost pile.

The windrow composting system is suitable for Indonesian conditions because of its flexibility (Kurnia et al., 2017). The advantages of the windrow composting system are that it is suitable for all types of organic waste, has a large loading capacity, and produces good quality compost (Lim et al., 2017). Therefore, the windrow composting method is suitable for biodegradable waste debris in Jakarta (Safira et al., 2021). The composting unit in Jakarta has applied the windrow composting method a lot, but it can only process a small part of the organic waste it contains (Pasang et al., 2007). Therefore, there is a need for biodegradable organic waste processing activities through various community empowerment programs.

4. Conclusions

In the composting method chosen, alternative 2. Judging from the distance between compost for workers' movement space, it can reach 1 m as in the material recovery facilities. Technical instructions that the land used for machine movement is reduced because it does not use machines. Therefore, limited land can be utilized for the amount of windrow so that the amount of waste processed can be more tremendous. This system utilizes natural air circulation. Optimization of the pile's width, height, and length is strongly influenced by the state of the raw material, humidity, pore space, and air circulation to reach the center of the pile of raw materials. In the future, this system will be a sound composting system. It has been successfully implemented in many places to process garden waste, municipal waste, sewage sludge, and manure for the amount of windrow. The amount of waste processed can be tremendous. To control the temperature, humidity, and oxygen in the windrow, a periodic reversal process is carried out, distinguishing it from other systems.

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