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Location Selection of Surabaya Landfill using Integration of the PROMETHEE and the AHP Methods

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ABSTRACT

Surabaya is the second-largest city in Indonesia. Like other major cities, Surabaya faces waste problems. The amount of waste produced by Surabaya residents has increased annually. This is partly due to the growing population. Currently, municipal waste management is still centralized in the Benowo Landfill. Owing to the increasing amount of waste and limited land available at the Benowo Landfill, a new landfill is needed. The selection of a landfill site is a complex problem because the selection criteria are multiple and conflicting with one another. The method used in this study is an integration of the PROMETHEE and AHP methods. The two MCDM methods were used to complement each other, and the weaknesses of one method were corrected by utilizing the strengths of the other, resulting in a better solution. This study aims to determine the location of a new landfill in Surabaya using the integration of the PROMETHEE and AHP methods. Based on the data processing that has been done, it is known that the new landfill location is in the Rungkut District.

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1. INTRODUCTION

Multi-Criteria Decision Making (MCDM) is a process of decision-making that considers multiple criteria when selecting an alternative, often in conflict with one another. Therefore, the resulting solution is a compromise and highly dependent on the decision-maker's preferences. MCDM has been developed over the past 35 years, and many methods for solving multiple-criteria problems have been discovered. Some well-known MCDM methods include PROMETHEE and AHP (Pohekar & Ramachandran, 2004).

The preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) was first developed by Brans in 1982, and then further developed by Brans and Vincke in 1985 and Brans and Mareschal (1994) (Brans et al., 1986; Brans & Mareschal, 2005). The Analytic Hierarchy Process (AHP) was developed by Thomas L. Saaty in 1982, 1988, and 1995 (Saaty, 1990; Saaty, 2008). Both MCDM methods have disadvantages and advantages when applied to decision-making problems. Therefore, a method improvement is needed, where the shortcomings of one method are overcome by using the advantages of another method, which can ultimately provide a better problem-solving process and can produce a better solution or decision (Macharis et al., 2004).

AHP is an MCDM method with several advantages that can be used to address the shortcomings of PROMETHEE. One disadvantage of PROMETHEE is the lack of problem hierarchy, which is crucial for a better understanding of problems. Another disadvantage is weighting, because there are no specific guidelines for weighting. These two disadvantages are the advantages of the AHP method that can be used to address the shortcomings of the PROMETHEE method (Macharis et al., 2004).

The PROMETHEE improvement method, integrating AHP, was applied to the problem of landfill (Final Disposal Site) site selection in Surabaya. Improving the PROMETHEE method through the integration of AHP improves the process of solving the landfill site selection problem, and the resulting solutions provide better decision-making alternatives.

To date, municipal waste management remains centralized in the Benowo Landfill (West Surabaya). The retrospective nature of mismanaged landfill management, both in Surabaya and other cities in Indonesia, further exacerbates the ongoing problems facing metropolitan cities. The Benowo Landfill currently serves 170 landfills (LPS) throughout Surabaya, with the largest number located in South Surabaya (47 LPS), followed by East Surabaya (47 LPS).

The current availability of a landfill in Benowo is ineffective in providing services throughout the city of Surabaya. Limited transportation facilities and the distance between the depots and the Benowo landfill have caused waste to accumulate, disrupting the city's cleanliness. Due to the increasing volume of waste and the limited space available for the Benowo landfill, the operational area of the waste beds has reached

capacity, necessitating the need for a new landfill.

Other studies that integrate the PROMETHEE and AHP methods include Siagian & Gwynne (2023), who used the integrated method to select and evaluate logistics outsourcing decisions. Furthermore, studies by Ajin et al. (2021) and Wardana et al. (2022) used the integrated method to select suppliers. Furthermore, Sikalo et al. (2023) used the integrated method to compare portfolio performance. Zhang et al. (2023) used an integrated method to evaluate the resilience of a sewer network. Tasić et al. (2024) applied the integration method to rank the profitability of investment projects. Sari et al. (2020) used the integration method to define suitable apiary locations. Komchornrit (2021) used the integration method to compare the financial performance of integrated logistics service providers.

The selection of a finalwaste disposal site (TPA) is a complex issue and requires an extensive evaluation process that considers the needs of the city, government, and regulations of the environment. Increasing population and environmental use require city planning criteria to fully identify the principles for determining the best location for waste disposal. Therefore, the selection and placement of landfill sites is a complex issue. Determining and evaluating the negative and positive characteristics of one location relative to another is a complicated task (Önüt & Soner, 2008).

The design of a waste management system involves selecting facilities for treatment and disposal, disposal locations, and transportation routes. Therefore, many other potential criteria, such as land capacity, community acceptability, investment costs, land use, and groundwater utilization, must be considered in the waste disposal site selection process. These criteria often conflict with each other. For example, the criteria for land capacity and community acceptability can conflict. It is possible for a location to have sufficient land capacity; however, the surrounding community is less receptive to landfills. These two criteria conflict, and can also occur with other criteria. Therefore, the selection of landfill sites can be viewed as a Multi-Criteria Decision-Making (MCDM) problem (Önüt & Soner, 2008).

2. RESEARCH METHODS

2.1. PROMETHEE Method

PROMETHEE is an outranking method that enriches dominant rankings (Brans et al., 1986). The PROMETHEE method provides a scale-independent representation of criteria and is easily understood by decision-makers (Briggs et al., 1990). PROMETHEE is a nonparametric outranking method for a limited set of alternatives. It is based on the negative (in-) and positive (out-) preference flows for each alternative in relation to the values of outranking to rank alternatives according to the selected preferences or weights. Positive flows express how much a specific alternative dominates another alternative, and negative flows express how much that alternative is dominated by another. The steps for applying PROMETHEE are as follows (Vego et al. 2008):

1. Create the matrix of impact
   A matrix of impact for selecting alternatives and criteria can be established using ordinal, qualitative, cardinal, or quantitative data.
2. Application of preference *P*(*a*,*b*)
   For every criterion, the selected preference function *P*(*a*,*b*) is applied to determine the extent to which outcome *a* is preferred over *P*(*a*,*b*).
3. Determining preference values
   Calculate the index of overall or global preference $\prod(a,b)$, which indicates the preference intensity for *a* over *b*.

$$\prod(a,b) = \frac{\sum_{j=1}^{k} w_j P_j(a,b)}{\sum_{j=1}^{k} w_j} \quad (1)$$

4. Calculating outranking flow
   In the PROMETHEE I, every $a \in A$ has a leaving flow or outranking with the following equation:

$$\theta^{+}(a) = \frac{1}{n-1} \sum_{b \in A} \prod(a,b) \quad (2)$$

   Where $\prod(a,b)$ indicates the preference that alternative *a* is better than alternative *b*. Leaving flow is the sum of the values of the curves pointing away from node *a* and is a characteristic of the outranking measure. Symmetrically, the entering flow is determined by the following equation:

$$\theta^{-}(a) = \frac{1}{n-1} \sum_{b \in A} \prod(b,a) \quad (3)$$

   Essentially, with the higher leaving flow and the lower entering flow, the better the alternative is considered (Vego et al., 2008). Therefore, PROMETHEE I provides alternatives of a partial ranking, but with more realistic information about incomparables. PROMETHEE II provides alternatives for a complete ranking of using net flows:

$$\theta(a) = \theta^{+}(a) - \theta^{-}(a) \quad (4)$$

   Partial information about incomparables is lost in PROMETHEE II.
5. Comparison of outranking flows
   A comparison of the outranking flows is given as follows:
   1. *a* is higher than *b* if: $\theta(a) > \theta(b)$, or; $\theta^{+}(a) > \theta^{+}(b)$ and $\theta^{-}(a) < \theta^{-}(b)$;
      $\theta^{+}(a) > \theta^{+}(b)$ and $\theta^{-}(a) = \theta^{-}(b)$;
      $\theta^{+}(a) = \theta^{+}(b)$ and $\theta^{-}(a) < \theta^{-}(b)$
   2. *a* is indifferent to *b* if: $\theta(a) = \theta(b)$ or $\theta^{+}(a) = \theta^{+}(b)$ and $\theta^{-}(a) = \theta^{-}(b)$

   The partial or complete ranking of a set of alternatives under consideration can be proposed to stakeholders to resolve decision-making problems.

2.2. AHP Method

The primary tool of the Analytic Hierarchy Process (AHP) is a hierarchy of functions, with human perception as its primary input. In a hierarchy, an unstructured and complex problem is disparted into groups and organized into a hierarchical form. The AHP model's approach is nearly identical to the political behavior model, namely, it models (individual) decisions using a collective approach to the decision-making process (Mahmoodzadeh et al., 2007).

The objective of using AHP is to identify preferred alternatives and rank them when all decision criteria have been considered simultaneously. The advantages

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of AHP are presented in Fig. 1 (Saaty, 1990).

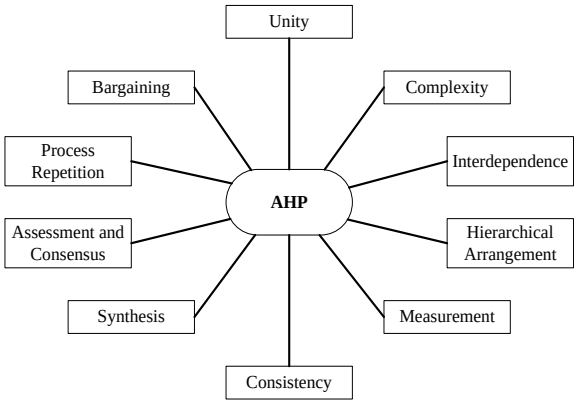


Fig. 1. The advantages of AHP

AHP is a multi-criteria decision-making tool that enables the consideration of non-financial and financial aspects, qualitative and quantitative measures, and the resulting trade-offs. The steps for solving the AHP method are as follows (Önüt & Soner, 2008):

1. Construct a pairwise comparison decision matrix (*A*)

$$A = [a_{im}] = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \dots & a_{1n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \dots & 1 \end{bmatrix} i, m = 1,2,\dots,n \quad (5)$$

C₁, C₂,...,Cₙ are defined as sets of elements, while a_{im} is represented as a quantitative assessment of a pair of elements, *Cᵢ* and *Cₘ*. Saaty based the scale of measurement for pairwise comparison. Therefore, verbal judgments can be represented by the levels of preference:

- Equally preferred = 1
- Moderately prefereed = 3
- Strongly preferred = 5
- Very strongly = 7, and
- Extremely preferred = 9

Values 2, 4, 6, and 8 are used as compromise values between the values mentioned.

2. Normalize the matrix of decision
   Every value of the column is summed, and then every value is divided by the total value of every column. Finally, the row average is calculated, and the decision maker's objective weights are obtained. A set of *n* numerical weights $w_1, w_2, \dots, w_i$ has been obtained.
3. Perform an analysis of consistency

$$A * w_i = \lambda i_{max},\ i = 1, 2, \dots, n. \quad (6)$$

The Consistency Index is calculated as follows:

$$CI = \frac{\lambda_{max}}{n-1} \quad (7)$$

The Consistency Index (CI) of a reciprocally generated random matrix can be referred to as the Random Index (*RI*), with reciprocal pressure. An average *RI* for reference matrices of orders 1–15 was generated using a sample size of 100. The final ratio to be calculated is the Consistency Ratio (*CR*). Typically, the resulting weights can be used if the *CR* is less than 0.1, and the assessment is consistent. CR is calculated as follows:

$$CR = \frac{CI}{RI} \quad (8)$$

2.3. Integration of PROMETHEE and AHP Methods

2.2.1. *Hierarchy*

The utilization of a tree structure to restructure decision-making problems is the advantage of the AHP method. This method enables decision-makers to achieve a more holistic view of the problem because it avoids compartmentalizing it into (subjective) selection components, which, when returned, can be subdivided into smaller elements. Fig. 2 shows the steps of the integration method.

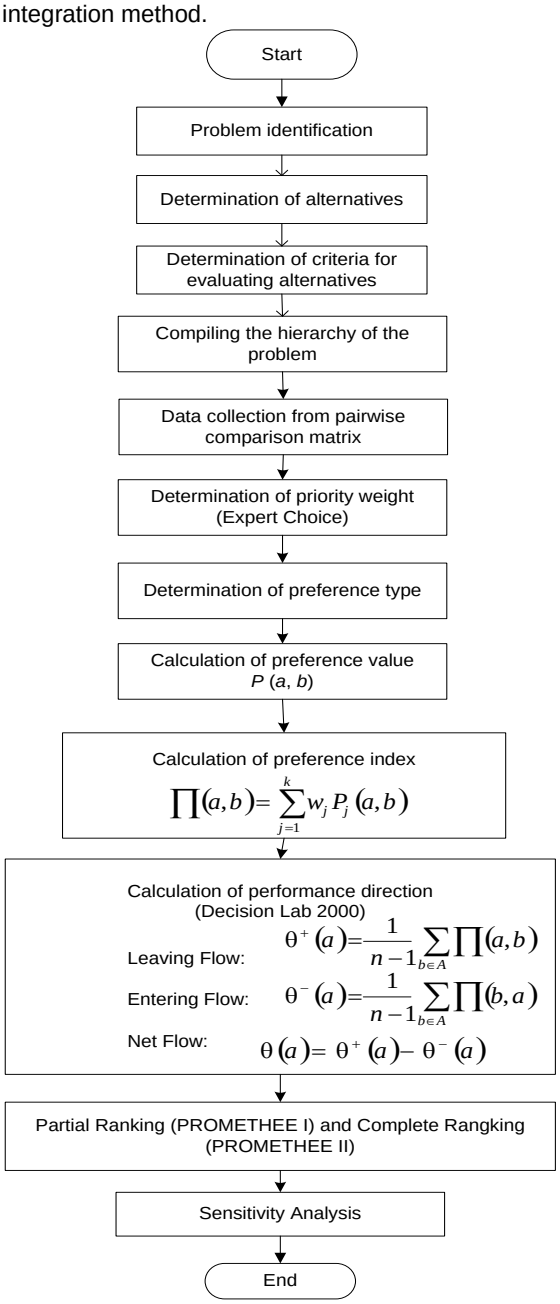


Fig. 2. The Flowchart of the integration method

Decision-makers sometimes encounter overly extensive tables of evaluation in PROMETHEE. The tables that can contain more than seven criteria and more than seven alternatives. PROMETHEE is more like a black box for solving decision-making problems. Adopting a tree structure can be considered an improvement to PROMETHEE.

Expanding PROMETHEE into a group environment using Decision Lab software provided the option of three levels within a model.

1. The first level enables analysis at the level of multiple individual decision-makers.
2. The various perspectives can then be aggregated under the bottom label.
3. The third level allows actions (or alternatives) to be aggregated into a specific group and subsequently treated as a single-action group.

The aggregation at the top level was based on the calculation of the sum of the net flow weights. If this idea is extended in the future, a hierarchical tree structure can be developed using PROMETHEE.

2.2.2. *Weight Determination*

A weight w_j = 1 can be determined for criterion *j* using PROMETHEE. The weight is gauged relative to the *j*-th criterion for each other criterion. The question to measure this weight is: "How much more important is criterion *i* than criterion *j* (considering the highest goal)?" At row *j*, when completing the AHP matrix, the question beseems: "How much more important is criterion *j* than criterion *i* (considering the highest goal)?" Therefore, this study has some limitations:

- A consistent matrix of pairwise comparison is required
- Following Saaty's rule (scale 1-9)

A single set of weights $w_j, j = 1, \ldots, n,$ is obtained, with *n* being the criteria number in PROMETHEE. When the matrix of pairwise comparisons has *n* columns, it leads to *n* sets of *n* weights. It ends up with a matrix of ranking if the matrix of pairwise comparison is consistent. Thus, there is a single linearly independent row, which, owing to the reciprocal nature of the matrix of pairwise comparison, is equivalent to a single linearly independent column. Here, it is permissible to imply the weights of a single set. In this statement, each column can be used to set the weight of PROMETHEE, since choosing $w_j = 1$ with respect to index *j* provides a relative gauge of the PROMETHEE weighting.

Table 1. Pairwise comparison matrix

DM	T_1	T_2	T_3
T_1	1	4	5
T_2	¼	1	3
T_3	1/5	1/3	1

Three criteria (T) are compared pairwise according to their relative importance to the decision maker (DM) in this matrix (Table 1). It is clear that this consistent matrix has rank 1, as the third and second rows are equivalent to the first row, divided by the third and second elements of the first row, respectively. For example, the second column (4, 1, 1/4) represents the PROMETHEE weights in the set. This yields the following basic observations:

- T_1 is moderately more important than T_2 in the decision process
- T_3 is less important than T_2 in the decision process

This statement is similar to what many people derive from the second column of the matrix of pairwise comparison, when viewed from the perspective of AHP. The second limitation is a consequence of the first. To ensure consistency of the matrix, the scale points 1–9 must be ignored. If this is acceptable, the problem is narrowed down to obtain a consistent matrix for decision makers.

3. RESULTS AND DISCUSSION

3.1. PROMAHP Application in Surabaya Landfill Location Selection

Surabaya is the second largest city in Indonesia. Like other major cities, Surabaya faces waste issues. The amount of waste produced by Surabaya residents increases annually. This is partly due to the growing population. Currently, the amount of waste entering landfill is 1,480 tons per day. Surabaya currently has one final waste disposal site: the Benowo Landfill. Benowo Landfill began operating in 2001, replacing the problematic Keputih Landfill. The Benowo Landfill covers approximately 34.27 hectares.

The even distribution of the population, both in the city center and in the suburbs, facilitates the transportation system, but on the other hand, it also presents challenges, such as the location of a landfill that can serve all waste sources. In reality, residential areas in Surabaya are still predominantly located in the eastern part of the city, whereas the currently operating landfill is located in the western part of Surabaya.

3.2. Alternative Locations

The Surabaya City Government plans to build a new landfill site in East Surabaya. In East Surabaya, seven districts could be used as alternative locations for the new landfill. Therefore, a selection process is needed for these seven districts to find the best location for the new landfill. These seven districts are as follows: Tambaksari, Gubeng, Rungkut, Tenggilis Mejoyo, Gunung Anyar, Sukolilo, and Mulyorejo (Fig.3).



Fig. 3. Surabaya district area

After brainstorming with the Surabaya City Sanitation and Parks Department, it was discovered

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that several sub-districts could not be used as alternative locations for TPA selection. This is because it is not possible for several sub-districts to become TPA locations because of the lack of land in the sub-district that can be used as a TPA location. Some of these sub-districts are: Tambak Sari, Gubeng, Tenggilis Mejoyo, and Mulyorejo. Because these four sub-districts cannot be used for alternative TPA selection, only three sub-districts in the East Surabaya area can be used for alternative selection: Rungkut, Gunung Anyar, and Sukolilo.

Table 2. Criteria description

No.	Abbreviation	Description
1	PT	Landowner
2	KL	Available land capacity
3	KPA	Relation to groundwater utilization
4	TS	Waste transportation (one-way trip)
5	JM	Access road to the landfill site
6	TG	Land use
7	KP	Agricultural conditions around the landfill
8	UU	Determination criteria/regulations
9	AM	Community acceptability
10	BI	Investment costs

Table 3. Sub-criteria description

No.	Abbreviation	Description
1	PT1	City/Central Government
2	PT2	Private (one)
3	PT3	Private/Company (one)
4	PT4	More than one right holder and/or ownership status
5	PT5	Social/Religious Organization
6	KPA1	Possible low limit with hydraulic limit
7	KPA2	Projected for utilization with hydraulic limit
8	KPA3	Projected for utilization without hydraulic limit
9	JM1	Flat with good condition
10	JM2	Flat with poor condition
11	JM3	Up/down
12	TG1	Has little impact on surrounding land use
13	TG2	Has moderate impact on surrounding land use
14	TG3	Has a large impact on surrounding land use
15	KP1	Located on unproductive land
16	KP2	No impact on surrounding location
17	KP3	Negative impact on surrounding agriculture
18	KP4	Located on productive agricultural land
19	AM1	Spontaneous
20	AM2	Moved
21	AM3	Negotiation

3.3. Location Selection Criteria

This research was conducted within the Surabaya City Sanitation and Parks Department. Therefore, the scenario used was limited to the department. The criteria were also determined by the Surabaya City Sanitation and Parks Department. After brainstorming with the department regarding the criteria for selecting a landfill site, 0 criteria (Table 2) and 21 sub-criteria were used (Table 3).

3.4. Hierarchy of Interests

In the application of PROMAHP, one of the improvements is the preparation of the problem hierarchy. With the existence of a hierarchy, it is possible to reorganize the problem into selection parts and build a hierarchy of criteria. Here, the importance of each element (criteria) is clear and helps decision makers achieve a better perspective on a problem. In this landfill site selection, there are four hierarchical levels: at level 1, there is the goal, namely, the selection of the landfill site; level 2, there are site selection criteria; level 3, there are sub-criteria for site selection; and level 4, there are alternatives for landfill site selection. In this landfill site selection, there are 10 criteria, 21 sub-criteria, and 3 alternative locations. Fig. 4 shows the hierarchy of interest for the problem of selecting a new landfill site.

3.5. Data Collection and Weighting

Weighting was performed by constructing a pairwise comparison matrix. The weighting data are obtained from a questionnaire distributed to relevant parties familiar with alternative landfill locations, namely the Surabaya City Sanitation and Parks Agency. The respondents rated the importance of each established criterion according to Saaty's rule using a scale of 1–9 for each pairwise comparison matrix. Eight respondents completed the questionnaire, all from the Surabaya City Sanitation and Parks Agency.

Table 4. Criteria priority weight

No.	Criteria	Priority	
		Local	Global
1	Available land capacity	0.200	0.200
2	Community acceptability	0.200	0.200
3	Land rights holde	0.122	0.122
4	Access road to the landfill site	0.122	0.122
5	Establishment criteria/regulations	0.092	0.092
6	Waste transportation (one way)	0.076	0.076
7	Link to groundwater utilization	0.061	0.061
8	Land use	0.061	0.061
9	Agricultural conditions around the landfill	0.039	0.039
10	Investment size	0.028	0.028
Inconsistency = 0.02			

Because there was more than one respondent, a geometric mean was calculated to obtain a single value from all the values. After calculating the geometric mean, the data were processed using Expert Choice

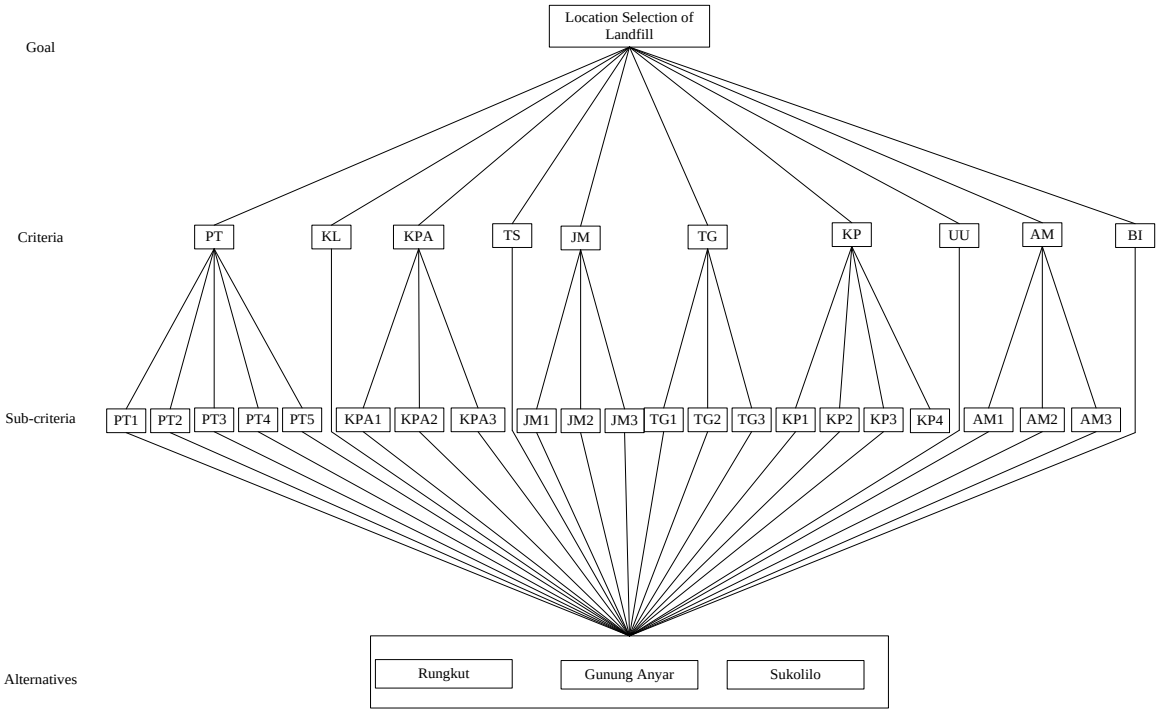


Fig. 4. Hierarchy of the interests

software. Following data processing, a judgment consistency test was performed. If the consistency ratio is above 10%, the assessment is repeated until a consistency level below 10% is achieved, as shown in Equation (8). The weighting of each criterion is presented in Table 4.

3.6. Preference Type

Each existing criterion is assigned a preference type to indicate the subjective preferences of decision-makers, which often have a significant influence on decisions or policies. Table 5 provides the preference types for each criterion.

Table 5. Preference type

No.	Criteria	Min/ Max	Preference Type
1	Landowner	Max	Type II
2	Available land capacity	Max	Type I
3	Relation to ground-water utilization	Max	Type IV
4	Waste transportation (one-way trip)	Max	Type IV
5	Access road to the landfill site	Max	Type I
6	Land use	Min	Type IV
7	Agricultural conditions around the landfill	Min	Type IV
8	Determination criteria/regulations	Min	Type IV
9	Community acceptability	Min	Type IV
10	Investment costs	Min	Type III

3.7. Parameter Value (Threshold)

The parameters for each criterion are determined based on the standard deviation values of the data obtained for each criterion, except for the land capacity and investment size criteria. The following is the calculation of the parameters (q, p) for each criterion (Table 6).

Table 6. Parameter values for each criteria

Criteria	Min/ Max	Parameters
Available land capacity	Max	q = 25 Ha
Community acceptability	Max	-
Landowner	Max	q = 0.0032; p = 0.0135
Access road to the landfill site	Max	q = 0.0085; p = 0.0363
Determination criteria/regulations	Max	-
Waste transportation (one-way trip)	Min	q = 0.0194; p = 0.0822
Link to groundwater utilization	Min	q = 0.0078; p = 0.0332
Land use	Min	q = 0.0079; p = 0.0334
Agricultural conditions around the landfill	Min	q = 0.0119; p = 0.0505
Investment size	Min	p = Rp28,000,000,000

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3.8. Preference Value

Based on data from the Department of Sanitation, values are generated for each alternative taking into account previously determined criteria (Table 7). With Equation 1, the preference value for each alternative is obtained (Table 8).

Table 7. Value of each alternative

Criteria	Alternatives		
	Rungkut	Gunung Anyar	Sukolilo
Available land capacity	10 Ha	8 Ha	14 Ha
Community acceptability	0.381	0.33	0.289
Landowner	0.343	0.342	0.315
Access road to the landfill site	0.358	0.358	0.284
Determination criteria/regulations	0.594	0.249	0.157
Waste transportation (one-way trip)	0.37	0.224	0.407
Link to groundwater utilization	0.295	0.332	0.373
Land use	0.311	0.311	0.379
Agricultural conditions around the landfill	0.299	0.402	0.299
Investment size	Rp 11,200, 000,000	Rp 8,960, 000,000	Rp 10,080, 000,000

Table 8. Preference value (*P*)

Alternatives	Rungkut	Gunung Anyar	Sukolilo
Rungkut	-	0.392	0.696
Gunung Anyar	0.077	-	0.735
Sukolilo	0.0011	0.039	-

3.9. Performance Direction

The performance direction calculations in this study used PROMETHEE software, Decision Lab 2000. Decision Lab 2000 is a further development of PROMCALC (PROMETHEE Calculation) software developed by Brans and Mareschal in 1994. Decision Lab 2000 software is an improved version of the PROMCALC software. Software of Decision Lab 2000 was developed by the Canadian company Visual Decisions Inc., in collaboration with the inventors of the PROMETHEE method, Professor Jean-Pierre Brans, and Professor Bertrand Mareschal at Brussels Free University, Belgium. The Decision Lab 2000 software is a Windows application that utilizes a spreadsheet-type interface for data processing and an interactive visual module, namely Geometrical Analysis for Interactive Assistance (GAIA), to comprehend the structure of MCDM problems (Brans & Mareschal, 2005).

The PROMETHEE I's partial ranking I can be seen in Fig. 5. The PROMETHEE I result indicated that there were no incomparable alternatives. For the Rungkut alternative with a leaving flow of 0.56, and an entering flow of 0.04, Gunung Anyar with a leaving flow of 0.41 and an entering flow of 0.21, and Sukolilo with a leaving flow of 0.01 and an entering flow of 0.73. The partial ranking of PROMETHEE I clearly shows that Rungkut is the first best alternative, followed by Gunung Anyar, and finally Sukolilo.

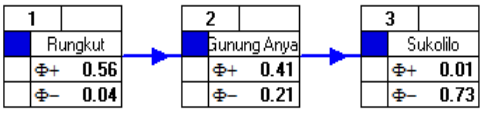


Fig. 5. Partial ranking

The PROMETHEE II's complete ranking can be seen in Fig. 6. It can be observed that Rungkut is the alternative with rank 1 (best location) with a net flow of 0.52, followed by Gunung Anyar alternative as rank 2 with a net flow of 0.20, and the worst alternative (rank 3) with a net flow of -0.72 is Sukolilo alternative.

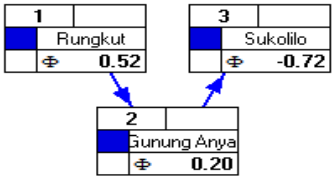


Fig. 6. Complete ranking

The Surabaya City Spatial Plan Three (Perda Kota Surabaya No. 3 Tahun 2025, 2025), it was only stated thalandfillsvelopment of new landfill would be in East Surabaya, North Surabaya, South Surabaya, and West Surabaya. No specific district has yet been decided. Therefore, this paper provides a solution to the needs of the government for the city of Surabaya.

The action profile window contained two independent panels. Each panel shows an alternative profile for every criterion. Fig. 7 shows that for the Rungkut alternative, the criteria for land rights, public roads, and land use perform equally well. However, the best criteria for the Rungkut alternative are groundwater utilization, agricultural conditions, regulations, and community acceptability. The available land capacity criterion performed moderately well. The information volume criterion performs poorly and the weakest criterion for Rungkut alternative is waste transportation.



Fig. 7. Action profile of Rungkut and Gunung Anyar

The criteria for groundwater utilization, agricultural conditions, regulations, and community acceptability performed better for the Rungkut alternative than for the Gunung Anyar alternative. The criteria that performed better for Gunung Anyar compared to Rungkut were waste transportation and investment size. For the

Gunung Anyar and Sukolilo action profiles, almost all criteria performed well, except for the information size criterion. Similarly, for Rungkut and Sukolilo action profiles, all criteria performed better for Rungkut than for Sukolilo.

The GAIA plane for the landfill site selection problem was obtained from the Decision Lab 2000 software. The GAIA plane gives the Decision Maker (DM) a comprehensive graphical representation of the decision-making problem and thus serves as a complementary explanation for the PROMETHEE ranking. The Δ value for the GAIA plane was 100%. According to the explanation of the GAIA plane, Δ greater than 75% indicates reliable information. The *pi* axis has a moderate length and lies between those of the Rungkut and Gunung Anyar alternatives.

The GAIA plane shows that the distance between *pi* and Rungkut is greater than that between *pi* and Gunung Anyar. Therefore, the best alternative in the GAIA plane is Rungkut. Based on the analysis described, if the decision-making body for selecting the landfill site is solely the Department of Sanitation and Parks, the decision would be highly accurate.

The walking weight view allows for modifying the criteria weights (by dragging the pointer at the bottom of the window) and observing the modified results in the form of PROMETHEE II rankings (Fig. 8). By simultaneously selecting multiple criteria, one can experiment with different weights.

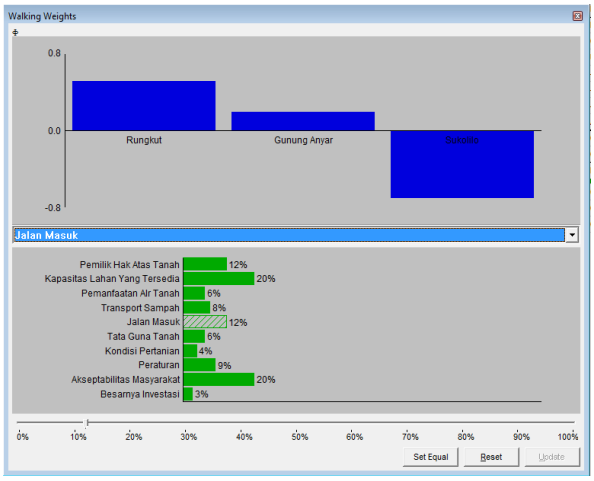
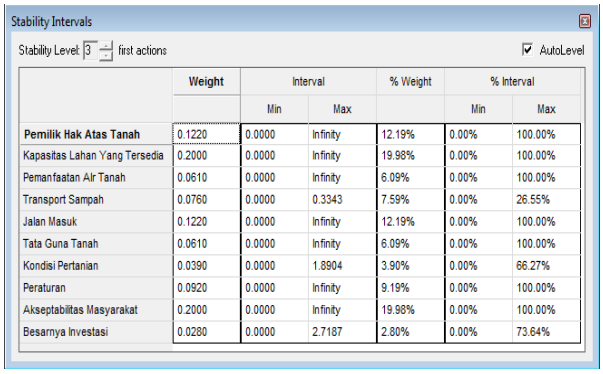


Fig. 8. Walking weights landfill site selection

3.10. Sensitivity Analysis

the stability interval results, which can be seen in Fig. 9. The stability interval indicates the limit to which the weight can be modified without affecting the complete ranking of PROMETHEE II for each criterion, provided that the weights of other criteria are not modified. For example, the weight of the land rights owner criterion can vary from a minimum weight (0%) to a maximum weight of 100% (infinity) without modifying the PROMETHEE II ranking. The weight of the waste transportation criterion can only be increased up to an interval of 0.3343 or up to 26.44%, but can be decreased to a minimum weight of 0%.


Stability Intervals

Stability Level: 3 first actions AutoLevel

	Weight	Interval		% Weight	% Interval	
		Min	Max		Min	Max
Pemilik Hak Atas Tanah	0.1220	0.0000	Infinity	12.19%	0.00%	100.00%
Kapasitas Lahan Yang Tersedia	0.2000	0.0000	Infinity	19.98%	0.00%	100.00%
Pemanfaatan Air Tanah	0.0610	0.0000	Infinity	6.09%	0.00%	100.00%
Transport Sampah	0.0760	0.0000	0.3343	7.59%	0.00%	26.55%
Jalan Masuk	0.1220	0.0000	Infinity	12.19%	0.00%	100.00%
Tata Guna Tanah	0.0610	0.0000	Infinity	6.09%	0.00%	100.00%
Kondisi Pertanian	0.0390	0.0000	1.8904	3.90%	0.00%	66.27%
Peraturan	0.0920	0.0000	Infinity	9.19%	0.00%	100.00%
Akseptabilitas Masyarakat	0.2000	0.0000	Infinity	19.98%	0.00%	100.00%
Besarnya Investasi	0.0280	0.0000	2.7187	2.80%	0.00%	73.64%

Fig. 9. Stability interval

4. CONCLUSION

The advantages of AHP, namely in problem structuring and weighting, are recommendations for improving PROMETHEE's shortcomings of PROMETHEE. Therefore, the PROMAHP method employs a hierarchy of importance that reorganizes the problem into selection components and establishes a hierarchy of criteria, thereby clarifying the importance of each element (criterion). The weighting in PROMAHP is based on the principle of pairwise comparison.

The selection of landfill sites is a case study in PROMAHP application, as site selection is an MCDM problem. There were ten selection criteria and three alternative locations. The ranking of PROMETHEE I results indicate that the best alternative in the partial ranking is the Rungkut alternative. The complete ranking of the PROMETHEE II results is consistent with the partial ranking of the PROMETHEE I results. Therefore, the best alternative for landfill site selection is the Rungkut alternative.

In future research, it is hoped that more than one preference (scenario) can be used to identify other possible conditions that can be considered simultaneously.

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