MULTI-CRITERIA EVALUATION OF TEMPORARY WASTE COLLECTION FACILITIES BASED ON THE LEVEL OF COMMUNITY INTEREST USING ANALYTICAL HIERARCHY PROCESS

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ABSTRACT: Waste management poses a complex challenge for governmental bodies. One of the challenges involves balancing the interests among various stakeholders, including city residents and local authorities, regarding the establishment of temporary waste collection facilities. A comprehensive examination of waste management issues should encompass operational, technical, financial, institutional, regulatory, and community aspects. This study aimed to evaluate and identify the criteria for the provision of temporary waste collection facilities and services from a community perspective. The criteria were determined by distributing open questionnaires to the community residing near the facilities. Additionally, reference studies were conducted to reinforce the community's perspectives. Analytical hierarchy process (AHP) was employed to determine the importance level of each criterion. The research was conducted in 75 facilities across three sectors (eight sub-districts) in Yogyakarta. Purposive sampling was utilised based on the population distribution in each sub-district, with the sample sizes determined using the Slovin method. The findings of the study showed that almost all sub-districts in these three sectors had two identical highest criteria: health (24%) and distance (22%). These criteria underscore the necessity for the government to prioritise health and distance considerations over the operational aspect of waste collection.

KEYWORDS: *Facility waste collection; Community perspective; Analytical hierarchy process; Importance level*

1.0 INTRODUCTION

The government, particularly the Environmental Service, has a responsibility to guarantee efficient urban waste management [1-2]. Urban waste management can be likened to a manufacturing system that manages resources into final products. The waste management procedure carried out by the Environmental Service begins with the provision of waste collection facilities, transportation vehicles, waste collection personnel, facility maintenance, and waste collection from each facility to the final disposal site (landfill). Similar to manufacturing, the Environmental Service must guarantee the effectiveness and efficiency of all processes.

Rapid population growth can lead to an increase in waste volume. According to the Yogyakarta Province Population Development Report [1], the population of the province increased by 0.44% from 2018 to 2022, while Yogyakarta City experienced a growth rate of 0.07% in the same period. Furthermore, Yogyakarta City recorded the lowest growth rate, in addition to the other four districts of Sleman, Bantul, Gunungkidul, and Kulon Progo. Despite this, Yogyakarta City stands out as the smallest and most densely populated area, with a population density of 12,701.45 people/km^2. This poses a challenge for the Environmental Service in providing temporary waste collection facilities due to limited land availability. As indicated in the Environmental Service Report [2], the waste volume generated in the Yogyakarta Special Region (DIY) from 2020 to 2023 is shown in Figure 1. Therefore, the Yogyakarta Provincial Environmental Service must provide facilities capable of accommodating this waste volume. These facilities must be located at several points close to the community or waste sources. Existing research on municipal solid waste (MSW) predominantly focuses on governmental perspectives, as they are responsible for urban waste collection [3-5]. Thus, waste management will be formulated based on several criteria: collection facility capacity, waste collection vehicle capacity, selection of facility locations, collection methods, collection scheduling, and collection vehicle routes. Neglecting to consider the community as users of the facilities can present a significant challenge.

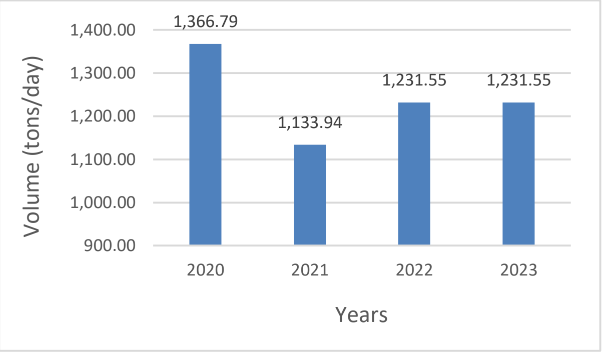

Figure 1: Waste generation growth in the DIY [2]

The complexity of the waste issue necessitates a comprehensive examination and resolution beyond governmental intervention. As a provider and manager of facilities, the government is obliged to evaluate several facilities that have been built. Effective and efficient MSW management has been widely accepted and recognised as a key factor in future social development, which requires technical innovation and also active engagement from all stakeholders, as well as social, economic, and psychological components [6-9]. Rubbyatna [9] explained that solid waste is closely related to technical, operational, financial, institutional, regulatory, and community aspects. Associations with social aspects can directly involve the community (assisting activities) or indirectly (financial, perception, and material needs).

The request to cease operations at several temporary waste collection sites in Yogyakarta City [2] underscores the importance of aligning the provided facilities with community needs. To the best of our knowledge and based on existing literature, there have been no studies on the development of temporary waste disposal facilities that incorporate considerations from the community using analytical hierarchy process (AHP). This study is crucial as it will enable the community to assess the advantages and disadvantages of these facilities. Several studies focusing on the social dimensions of municipal waste management [8–10] offer a framework for future management practices. The current study attempts to identify the social dimensions of the factors required for the establishment of temporary waste collection sites from the community's perspective.

This study will serve as the basis for further research on integrated municipal waste management, encompassing technical, economic, and social aspects. Several previous studies on urban waste management have focused on the government's waste collection requirements and facility allocation, with emerging considerations for new social and community dimensions as a framework. The uniqueness of this study is that it identifies the technical needs of the community for the development of temporary waste collection facilities using the AHP method. It is expected that this study can provide input that bridges the community needs and the government, with the hope that the community will pleasantly collect waste through the optimisation of facilities available in the area where they live.

2.0 METHODOLOGY

This study proposed the steps illustrated in Figure 2 for evaluating temporary waste collection facilities based on the level of community interest. The research involved five stages of investigation: direct engagement with the community, literature review, instrument design, AHP processing, and final analysis and evaluation. The study was conducted across eight regions, or sub-districts, which serve as sources of waste or areas with waste demand.

The research begins by identifying or exploring the attributes that the public will consider through an open questionnaire. Several direct actors (waste-producing communities) and waste-sorting officers at the Temporary Waste Disposal Site (TWDS) were assessed. The respondents were gathered, representing eight regions. The results of the public opinion were then adjusted with the results of literature studies [8-9], [11-12] to establish seven criteria and twenty-eight sub-criteria for the questionnaire instrument. Prior to distributing the instrument to respondents, it was reviewed together with the Head of the Waste Management Division of the Environmental Service. Subsequently, the respondent's assessment was processed to calculate the consistency ratio of the assessment. The overall assessment results are considered consistent if the consistency index is less than 0.1. Accordingly, the study progressed with the evaluation, synthesis, and conclusions.

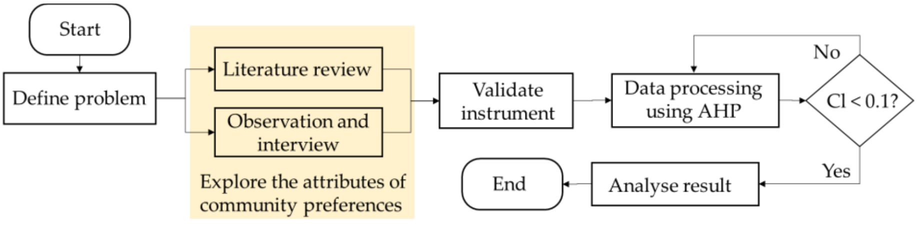

Figure 2: Flow process diagram

The primary research subjects in this study were individuals residing near 75 facility points located in eight sub-districts, R1–R8 [11]. The sampling technique employed was purposive sampling, which was based on the proportion of the population in each sub-district. The respondents include residents or waste managers in the vicinity of the facility point. The number of samples was determined using Slovin's method [13]. This formula is part of simple random sampling. The formula is n = N/(1 + N(e^2)), where n is the desired sample size, N is the population size, and e is the margin of error. Secondary data obtained indirectly from sources related to this research were also used, namely observation and reference data.

Several methods were employed to collect criteria and data ranking criteria, including observation, interviews, and questionnaires. Research observations were carried out by directly observing the surrounding conditions, while interviews were conducted by asking questions directly to the informant. These procedures were continued until seven criteria and twenty-eight sub-criteria were obtained.

The decision-making process involves many decision-makers, with many of the criteria most frequently used by previous researchers [14-16] are derived from the AHP. An essential aspect that is occasionally overlooked is the consideration of the actors or users [9]. Given the dynamics of today's ever-changing environment that has never been seen before, making informed decisions based on adequate and aligned goals is crucial, especially for organisational survival.

The procedures or steps for the AHP are as follows [17]:

i. Defining the problem and setting goals. If the AHP is used to choose alternatives or set alternative priorities, an alternative development is carried out at this stage.
ii. Arranging problems into a hierarchy so that complex problems can be viewed in detail and are measurable.
iii. Determining weighting or contributing factors to achieve the objectives, where the component with the highest weight has priority handling. The priority results from a pairwise comparison matrix between all elements at the same hierarchical level can be determined using Equation 1:

$$\gamma_{max} = \frac{\gamma_{max_{k_1}} - \gamma_{max_{k_n}}}{n} \tag{1}$$

iv. Calculating the consistency index (CI) using Equation 2:

$$CI = \frac{Y_{max}}{n-1} \tag{2}$$

v. Conducting consistency ratio (CR) testing for the comparison between the elements obtained in each hierarchy using Equation 3:

$$CR = \frac{CI}{RI} \quad (3)$$

Where CI is between 0 and 0.1; hence, the weighting of the criteria is accepted.

3.0 RESULTS AND DISCUSSION

Based on the procedures or initial steps of the AHP, this research is motivated by the issue of inefficiency in government-provided facilities. Hence, there is a need for conducting an evaluation. The assessment emphasises the aspects of the community's perspective on what and how the community's needs for temporary waste collection facilities are prioritised.

Table 1. District, population, area, and number of facilities [18]

Regiona l Code	District/Region	Number of Population (people)	Area (km^2)	Population Density (people/km^2)	Number of TWDS
R1	Pakualaman	10,716	0.63	17,010	7
R2	Wirobrajan	27,746	1.76	5,139	5
R3	Danurejan	21,121	1.1	19,201	12
R4	Kraton	21,939	1.4	15,671	5
R5	Kotagede	33,535	3.07	10,924	7
R6	Mergangsan	31,986	2.31	13,847	7
R7	Umbulharjo	68,760	8.12	8,468	24
R8	Mantijeron	35,207	2.61	13,490	8
	TOTAL	251,010	24.64		75

The research was conducted in eight sub-districts in the city of Yogyakarta. The government has provided 75 designated facilities in these eight sub-districts, namely Pakualaman, Wirobrajan, Danurejan, Kraton, Kotagede, Mergangsan, Umbulharjo, and Matrijeron. Table 1 presents the conditions of each region. R7 stands out as a sub-district with the highest population and largest area, where the government has provided the highest number of temporary waste disposal sites (24 facilities). Meanwhile, R1 and R3 are provided with a relatively large number of facilities (7 and 12 facilities, respectively) to accommodate their high population densities. Despite its considerable size, R2 has been allocated with only five facilities.

The identification of needs was performed on 30 respondents from the community surrounding the facility points. Figure 3 presents the results of open identification combined with literature studies, resulting in seven criteria and seventeen sub-criteria. The seven criteria identified include distance, accessibility, comfort, capacity, health, management, and facilities. Subsequently, the details of the criteria, sub-criteria, and indicators for each criterion are outlined in Table 2, serving as the basis for developing a questionnaire to determine the level of importance, which was examined for face validity [9], [19] prior to distribution. With a total population of 251,010 people across three sectors and an error rate of 10%, the application of the Slovin's formula determined that 100 respondents should be chosen. The distribution of respondents was then allocated proportionally across eight sub-districts.

The AHP method was employed to process the data according to their respective levels of importance (weighting). Respondents representing the community were questioned to compare one criterion against another, followed by one sub-criterion against another. Other alternatives were not employed in this research; therefore, data processing was stopped once the weight or level of importance for each criterion and sub-criterion had been determined.

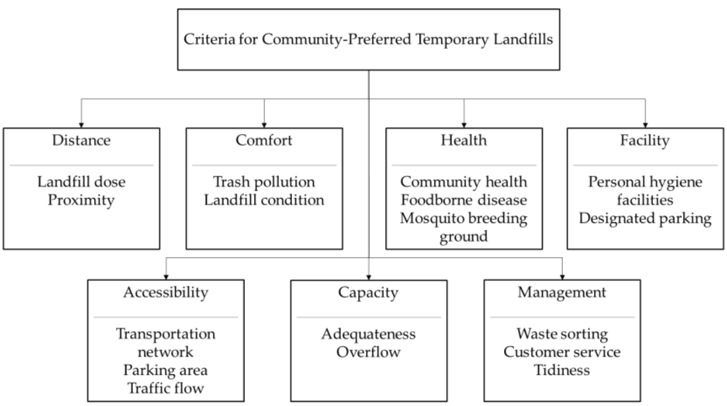

Figure 3: Proposed criteria to determine temporary landfills based on community preferences

Table 2: Criteria, sub-criteria, and indicators for this study

Dimension	Sub-criteria	Indicators
1. Distance (J)	1.1 Landfill dose	1.1.1. Landfill dose to residential areas

		1.1.2. Landfill dose to trading activities
	1.2 Proximity	1.2.3. Proximity to office and educational
		1.2.4. Individual waste sources close to the landfill
2. Accessibility (A)	2.1. Transportation network	2.1.1. The location of the landfill is connected to the highway
		2.1.2. The location of the landfill is free from the disturbance of heavy road traffic
	2.2. Parking area	2.2.3. A parking area is available at the landfill location
	2.3. Traffic flow	2.3.1. There is no traffic jam along the road to the landfill
		2.3.2. Ease of transportation (dump truck/amroll truck) without being hindered by heavy traffic at the landfill location
3. Comfort (K)	3.1 Trash pollution	3.1.1. Comfortness around the location due to spilled dry or wet trash
		3.1.2. Flood-free and not in the river channel area
		3.1.3. No strong odor around the landfill
	3.2. Landfill condition	3.2.1. The condition of the landfill was not damaged
4. Capacity (KL)	4.1. Adequateness	4.1.1. Location of land is available with an adequate land area.
		4.1.2. Capacity to contain a significant amount of garbage
	4.2. Overflow	4.2.1. No trash is scattered or overflowing beyond its volume limit
		4.2.2. The needs to expand landfill capacity
5. Health (KS)	5.1 Community health	5.1.1. The existence of landfill does not disturb the health of the surrounding community
	5.2. Foodborne disease	5.2.1. The existence of landfill does not cause diarrhea
	5.3. Mosquito breeding ground	5.3.1. The existence of landfill does not cause chikungunya disease
		5.3.2. The existence of landfill does not cause the development of flies, mosquitoes and mice
6. Management (P)	6.1. Waste sorting	6.1.1. There is a systematic separation of different types of waste materials upon their arrival or during processing at the landfill site
	6.2. Customer service	6.2.1. The manager/ staff serves in friendly manners
		6.2.2. There is a need for a manager at the landfill
	6.3. Tidiness	6.3.1. The landfill is tidy due to the segregated waste
7. Facility (F)	7.1. Personal hygiene facilities	7.1.1. Hand washing facilities are available at the landfill
		7.1.2. Toilets are available based on gender
	7.2. Designated parking	7.2.1. Designated parking for customers are available

The assessment scores from 100 respondents in each region were added using the geometric mean method. Table 3 presents the pairwise comparison values for the criterion levels. The weight normalisation (Table 4) for each pair of criteria involves dividing the value in Table 2 by the total weight value for each criterion or each column. Subsequently, the weight value for each criterion (γ_{max}) was calculated using the normalisation method (Equation 1), as shown in the last column of Table 4.

Table 3: Pair-wise comparison matrix of criteria

Criteria	J	A	K	KL	KS	P	F
J	1	2.09	2.04	2.44	0.79	1.87	2.56
A	0.48	1	1.70	1.90	0.54	1.56	2.25
K	0.49	0.59	1	1.33	0.50	1.15	2.03
KL	0.41	0.53	0.75	1	0.36	0.93	1.55
KS	1.27	1.86	2.02	2.78	1	2.07	2.79
P	0.53	0.64	0.87	1.07	0.48	1	1.91
F	0.39	0.44	0.49	0.64	0.36	0.52	1
Total per criteria	4.57	7.14	8.87	11.17	4.02	9.12	14.08

Table 4: Normalisation matrix of criteria

Criteria	J	A	K	KL	KS	P	F	Weight (γ max)
J	0.22	0.29	0.23	0.22	0.20	0.21	0.18	0.22
A	0.10	0.14	0.19	0.17	0.13	0.17	0.16	0.15
K	0.11	0.08	0.11	0.12	0.12	0.13	0.14	0.12
KL	0.09	0.07	0.08	0.09	0.09	0.10	0.11	0.09
KS	0.28	0.26	0.23	0.25	0.25	0.23	0.20	0.24
P	0.12	0.09	0.10	0.10	0.12	0.11	0.14	0.11
F	0.09	0.06	0.06	0.06	0.09	0.06	0.07	0.07

Table 5: Random consistency index

Size of Matrix (N)	3	4	5	6	7	8	9	10	11	12
Random index (RI)	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.54

Table 6: RI, CI, and CR for each region

	R1	R2	R3	R4	R5	R6	R7	R8
Random index (RI)	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32
Consistency index (CI)	0.05	0.07	0.06	0.03	0.03	0.03	0.01	0.03
Consistency ratio (CR)	0.04	0.05	0.05	0.02	0.02	0.02	0.01	0.02

The AHP justifies the CR to assess the consistency of respondents' assessments. The CR was determined by comparing the CI to the RI. The formula for calculating the CI is presented in Equation 2, while the RI can be found in Table 2. As seven criteria were used in prioritizing the TWDS, the RI for this study was 1.32. The CR (Equation 3) for both criteria and sub-criteria was less than 0.1; thus, the results of the respondents' assessments in these eight areas are consistent (Table 5).

The criteria and their respective sub-criteria (global weights, and rankings). were ranked after all the weights of all respondents' criteria and sub-criteria were determined to be consistent. The global order was obtained by indexing the weights of all sub-criteria to determine the global weights as summarized in Table 5. Column 2 in Table 7 represents the γ_{max} weight. In order to calculate the weight of each sub-criterion, the γ_{max} value of each pairwise value in the sub-criterion is multiplied by the maximum weight of the criteria to obtain a global weight value, which is then used to determine the ranking for all criteria and sub-criteria as in column 7. Criteria KS has the highest global weight (0.24) and is ranked first, indicating its significant impact, particularly driven by sub-criterion KS1. Criteria J follows with a weight of 0.22, with J2 being the most influential sub-criterion. Criteria A, K, KL, P, and F have lower weights, with A and K having moderate influence, while KL, P, and F are less significant. Each sub-criterion's weight contributes to the overall importance and ranking of its respective criterion.

Table 7: Weight, global weight, and ranking of all criteria and sub-criteria

Criteria		Sub-Criteria		Global Weight	Ranking
J	0.22	J1	0.34	0.08	2
		J2	0.35	0.08	
		J3	0.19	0.04	
		J4	0.12	0.03	
A	0.15	A1	0.16	0.02	3
		A2	0.26	0.04	
		A3	0.15	0.02	
		A4	0.18	0.03	
		A5	0.25	0.04	
K	0.12	K1	0.35	0.04	4
		K2	0.29	0.03	
		K3	0.23	0.03	
		K4	0.13	0.01	
KL	0.09	KL1	0.22	0.02	6
		KL2	0.22	0.02	
		KL3	0.44	0.04	
		KL4	0.12	0.01	
KS	0.24	KS1	0.41	0.10	1
		KS2	0.22	0.05	
		KS3	0.22	0.05	
		KS4	0.15	0.04	
P	0.11	P1	0.32	0.04	5
		P2	0.18	0.02	
		P3	0.21	0.02	

		P4	0.28	0.03	
F	0.07	F1	0.40	0.03	7
		F2	0.20	0.01	
		F3	0.40	0.03	

The regression analysis shows a strong fit with an R-squared value of 0.931, indicating that the model explains a significant portion of the variance in the rankings. The coefficients reveal that an increase in global weight significantly lowers the ranking (better performance), while an increase in sub-criteria weight slightly increases the ranking (worse performance). The intercept of 8.05 provides a baseline ranking. The predicted rankings closely match the actual rankings, validating the model's accuracy. For example, KS1, with the highest global weight, has a predicted ranking of 1.14, aligning well with its actual ranking of 1. Similarly, other criteria like J and A also show predicted rankings that are close to their actual rankings, demonstrating the model's reliability. Overall, the analysis confirms the significant impact of global weights on the rankings and provides a robust method for predicting performance based on these weights. The result is summarized in Figure 4.

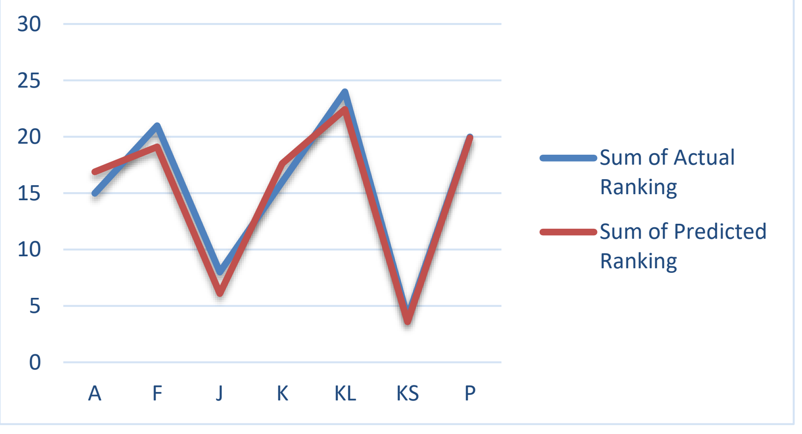

Figure 4: Regression analysis

Figure 5 illustrates the results of applying the AHP method to evaluate the importance levels of the seven criteria across eight sub-districts. In the figure, the 'health' criterion (light blue colour) is the most important criterion in the global calculation. Specifically, the 'health' criterion is the most critical factor in four sub-districts (R1, R3, R6, and R7). Meanwhile, the 'distance' criterion (blue marine colour) is the most important factor in sub-districts R2, R4, and R5, followed by the 'health' criterion. Due to the absence of a partial determination by the government, priority considerations regarding facility development were determined based on global calculations, as presented in Table 6.

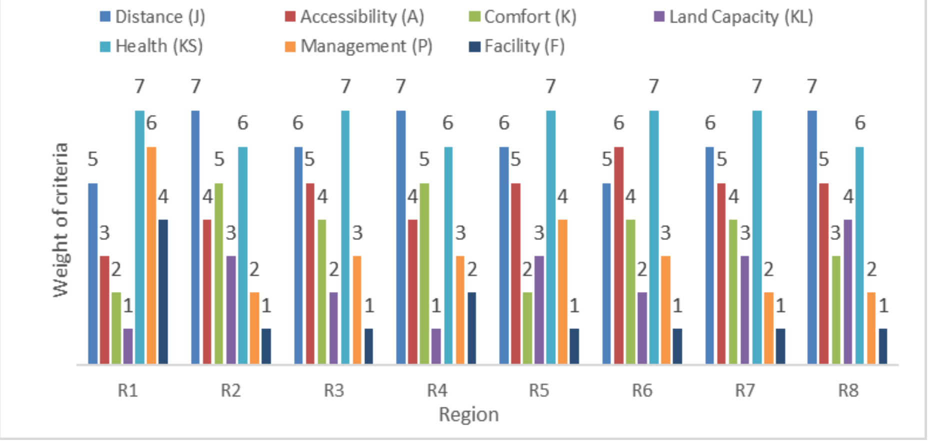

Figure 5: The results of weight processing for each criterion from eight regions

Additionally, Figure 6 displays a comparison between the scores for each sub-criterion and the global weight scores. It can be seen that the 'facility' criterion achieved relatively high scores but scored low globally. This trend is particularly noticeable in the R1 region, which has the smallest area. Nevertheless, almost all respondents stated that facilities really need to be prioritised.

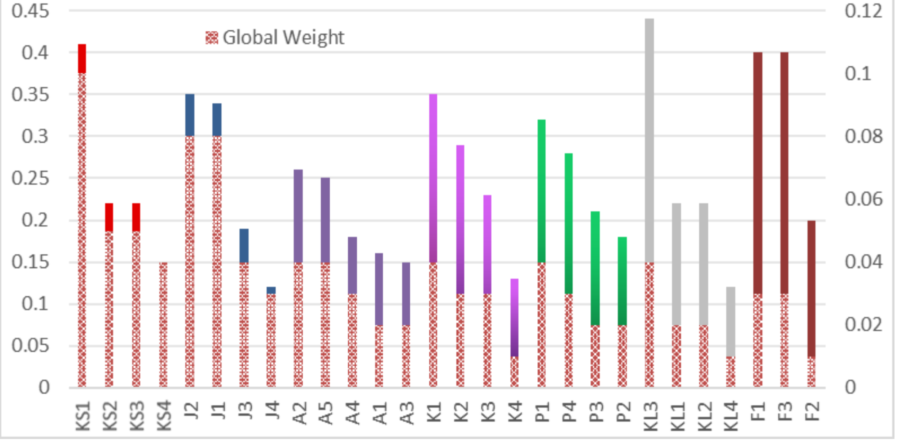

Figure 6: Comparison between scores and global weights for all sub-criteria

The 'health' criterion has the most significant weighting. This finding aligns with the assertion made by Ma and Hipel [8] that temporary waste collection can have implications on public health, especially for vulnerable groups. Waste collection facilities should prioritise the management of environmental pollution caused by microorganisms that can accumulate in soil, water, and living organisms. The integration of health criteria in developing waste collection facilities should be a key component of waste management policies for regional governments of a country [20].

Distance and accessibility are the second-most important factors that are necessary for either the community when collecting waste from their residences to facilities or for the government (Environmental Service) when collecting waste from collection facilities to the final disposal sites. This result is consistent with previous research by Yeomans [5], where individuals prefer a waste facility that is close to their residence. They also need facilities that are easily accessible; if necessary, they do not have to exit their vehicles (drive-through). People living in close proximity to waste facilities demand comfort by eliminating unpleasant views and smells. Therefore, initial management and processing are required, such as selecting types of organic and non-organic waste, recyclable waste, and hazardous waste. Accordingly, these facilities should have an adequate facility area to accommodate waste from the surrounding community for sorting and accessing waste collection vehicles

The results of community considerations can then be used to develop a model for determining facilities from the social aspect. The model for determining facilities based on the social aspect can then be integrated into a large city waste management model. Previous researchers stated that waste management in large cities must be integrated, holistic, and systemic [3, 5, 21-22]. Apart from that, waste management must also be a solution accepted by the community, which emphasises the preservation of the environment and the selection of affordable technology that guarantees public health [20].

Integrated large city waste management, which must be aligned with social sustainability, can be included in the development of the network model [23]. Several factors and asset characteristics are closely related to various sustainability dimensions: environmental (gas emissions and solid waste management), social (health and welfare, safety, and social justice), and economic (improving the circular economy and maintaining industries that are sensitive to image) [3], [22].

4.0 CONCLUSIONS

In short, the objective of this research in identifying the criteria for constructing temporary waste collection facilities has been achieved. In general, the community in eight sub-districts agreed that seven criteria need to be considered when constructing temporary waste collection facilities. Based on the level of global importance, the existence of sub-criteria for temporary waste facilities does not harm the surrounding community's health. The 'health' criterion has the highest priority, which indicates that it is the most critical factor followed by the distance of the temporary landfill. This will act as a guide for the decision-making process, where planners and policymakers can prioritize health and distance considerations to ensure the effective and sustainable placement of temporary waste collection facilities.

AUTHOR CONTRIBUTIONS

A. Purwani: Conceptualization, methodology, reviewing and editing; S. Fauzia: Data curation and writing-original draft preparation; U. Linarti and M.H.F. Md Fauadi: Software, validation and editing; A. Haryoko: Data source and validation

CONFLICTS OF INTEREST

The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have approved the review, agree with its submission and declare no conflict of interest on the manuscript.

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