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Evaluating Municipal Solid Waste Disposal Options by AHP-based Linguistic Variable Weight

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Abstract The increase in municipal solid waste (MSW) being generated each year poses a serious dilemma in choosing the best MSW disposal system in Malaysia. Since the decision process involves uncertainty, multiple considerations, and incomplete datasets, a simple and efficient method is urgently required in order to achieve a better decision. This paper carried out the new approach in analytic hierarchy process which utilised the linguistic variables in order to derive the relative weights of each investigation attributes. The approach employs the natural expression judgment to quantify all the qualitative dataset related to MSW disposal problems in the studied areas. To demonstrate the feasibility of the proposed method, a case study in the state of Selangor and Kuala Lumpur Federal Territory was employed. It was found that the approach has great potential to deal with the uncertainty of datasets. Additionally, the approach is also very practical and user friendly since the decision makers can easily evaluate the attributes using linguistic expressions fully. Finally, the method also considers the human rethinking-model in line with human nature that uses linguistic expressions to track subjectivity.

Keywords Analytic hierarchy process (AHP); linguistic hedges; linguistic variable weights; municipal solid waste (MSW) disposal.

1 Introduction

Recently, the tremendous increase in municipal solid waste (MSW) generation in Malaysia has received significant attention from both government and public constituencies. MSW management particularly with regards to the disposal system is becoming a serious burden especially in the central areas of Peninsular Malaysia. For instance, the state of Selangor and Kuala Lumpur Federal Territory (KLFT) recorded the highest MSW generation (2.32 million tonnes yearly) which constitutes one-third of the overall MSW generation in Malaysia [1]. This huge amount of solid waste could not be absorbed totally by existing disposal sites which practice either traditional landfill or open dumping.

Presently, the number of available landfill is limited and more than half of existing landfills are nearly reaching the maximum capacity to receive any MSW disposal. The environmental pollution, leachate problems, disturbing odour, and opposition by the surrounding community are some challenges faced by the government before considering opening any additional landfill site. Moreover, the poor site design, inadequate compaction, lack of leachate collection and treatment system, shortage of landfill covering are also other common problems experienced in most developing countries including Malaysia. These problems occur because almost 90 percent of all landfills are non-engineered open dumping disposal facilities [2]. This situation will create considerable health and environmental problems if the potential adverse impacts are not monitored carefully.

Several efforts such as to construct new disposal sites and extend the existing landfills are reviewed carefully. As a result, other disposal methods such as incineration, composting and material recycling are considered as the best compromising alternative to overcome problems in the long run. However, in order to identify the most suitable disposal system, a feasible method is required since it involves a multi-criteria consideration, multiple stakeholders and various respective criterion and sub-criterion. Since the decision process itself involves uncertainty, lacks initial information, quantitative and qualitative factors, a comprehensive decision-making model should be proposed.

In order to come up with more flexible and robust models, international researches have concentrated on the development of an integrated MSW model. For instance, Hung et al. [3], overcame the conflicts that arise from stakeholders and the feasibility of the decision; Daskalopoulos et al. [4], developed integrated model that focused on economic and environmental aspects; Huang et al. [5], proposed a MSW management system; Klang et al. [6], evaluated waste management systems; Su et al. [7], predicted the possible implementation decision-making MSW framework.

Many studies have also focused on the Decision Support System (DSS); Elimination Et Choice by Translating Reality III (ELECTRE III) [8]; spatial decision support system (SDSS) [9]; Geography Information Systems (GIS) and Analytic Hierarchy Process (AHP) [10]. However, three models were identified as being often used [11]; Multi-Criteria Decision Making (MCDM) and Multi-Objective Programming (MOP), as well as Life Cycle Assessment (LCA). MCDM is used for choosing the best model among several alternatives by considering many criteria. AHP is employed for solving environmental problem with multiple-criteria [12], TOPSIS method [13], and outranking method [14], while MOP is used for choosing the locating sites and management strategies [15]. Conversely, LCA is usually used to evaluate the environmental impact of the alternatives for MSW management [16 – 18].

Based on the development above, existing research very rarely explores and utilises the AHP-based linguistic variable weight or namely linguistic hedges. The AHP method has potentials to evaluate the attributes using simple and systematic manner as well as able to deal with variety of input data (i.e., crisp, quantitative, and qualitative) in the decision process. Hence, the objective of this paper is to evaluate the MSW disposal options using AHP-based linguistic hedges. For that purpose, this paper is divided into five sections. In Section 2, the background of the decision-making tools is briefly reviewed and the proposed approach is explained in Section 3. An application via a case study to demonstrate the proposed approach is explained in Section 4 and conclusion is made in Section 5.

2 Background of the Decision-Making Tools

2.1 Analytic Hierarchy Process

Analytic Hierarchy Process (AHP) was introduced by Saaty [19] and is one of the widely accepted methods used in Multi-Criteria Decision Making (MCDM) problems. It offers systematic approaches to alternative selection and justification problem by using the hierarchical structure analysis and concepts of fuzzy set theory [20]. Recent researches have utilised the Saaty AHP method to solve various MCDM problems [21-25].

Although the AHP approach has attracted criticism for certain aspects [26-27], it is still very popular due to its ability to structure a complex, multi-person and multi-attribute problem hierarchically, and it allows one to investigate each level of the hierarchy separately, combining the results as the analysis progresses [28]. Basically, the AHP method consists of four main steps:

(i) Structure the hierarchy of criteria and alternatives for evaluation;

(ii) Establish a pair-wise comparison to assess the decision-makers' evaluation;

(iii) Obtain the priorities for criteria and the alternatives using eigenvector method, and

(iv) Synthesise the priorities of the alternatives according to the criteria to rate the alternatives for performance score calculation.

In general, the calculation to obtain the performance score (P_k) for each alternative using the hierarchical structure is shown in Figure 1. Thus, the final decision is referred to the largest P_k. The larger the performance score value, the better the performance of the alternative.

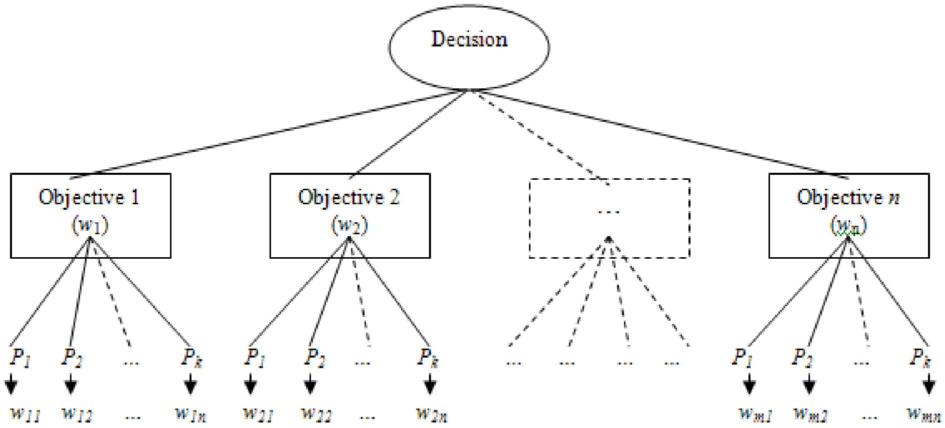


Figure 1: The Hierarchy Structure in AHP

The crisp $1 - 9$ scale is used in earlier versions of AHP for pair-wise comparison assessment. However, in real application, the Decision Makers (DMs) prefer a flexible judgment rather than sharp numerical values in assessing a process. For instance, the numeric value such as 5 or 9 etc. cannot represent efficiently in pair-wise comparison process compared with the approximate values. For this reason, many researchers found that the classical AHP approach has some shortcomings [20, 29-30], identified as follows:

(i) It may not yield a satisfactory result due to the nature of information being usually subjective and intangible;

(ii) It does not take into account the uncertainty aspects of the input data;

(iii) It creates and deals with a very unbalanced scale of judgments;

(iv) The method is rather imprecise in ranking process.

Therefore, in this research the linguistic hedge was utilised to derive the importance of the relative weights for each criterion in the decision process. The next sub-section briefly discusses this concern.

2.2 Linguistic Hedges

In our daily life, we often use more than one word to describe a variable. For example, after we test drive a car and give the rating by linguistic variables, then its values might be '*very comfortable*', '*slightly comfortable*', '*more or less comfortable*', etc. Thus, the words such as "*very*", '*slightly*', "*more or less*" are called linguistic hedges.

Definition 1 A linguistic hedge or a modifier is an operation that modifies the meaning of a term more generally of a fuzzy set. If $\tilde{A}$ is a fuzzy set, then the modifier k generates the (composite) term $\tilde{B} = k\left(\tilde{A}\right)$. The modifiers used frequently are:

Concentration

$$\mu_{con\,(\tilde{A})}(x) = \left[\mu_{\tilde{A}}(x)\right]^n; \quad n \quad \in [1, 8] \tag{1}$$

Dilation

$$\mu_{dil\,(\tilde{A})}(x) = \left[\mu_{\tilde{A}}(x)\right]^{1/n}; \quad n \quad \in [1, 4] \tag{2}$$

where both n is a power of *dilation*/*concentration* (i.e., linguistic hedge).

Definition 2 The linguistic hedges and their approximate meanings are specifically classified as shown in Table 1.

Table 1: The Hedge Values of the Specific *Dilation* and/or *Concentration* [31]

Linguistic hedges	Meaning	Hedge type	Hedge values ($\boldsymbol{n}$)
Very A	Intensify a fuzzy region	*Concentration*	$[\mu_{veryA}(x)]^3$
Positively A	Contrast intensification	*Concentration*	$[\mu_{positivelyA}(x)]^2$
A (i.e., no hedges)	–	–	$[\mu_A(x)]^1$
Usually A	Contrast diffusion	*Dilation*	$[\mu_{usuallyA}(x)]^{1/2}$
Somewhat A	Dilate a fuzzy region	*Dilation*	$[\mu_{somewhatA}(x)]^{1/4}$
Between above linguistic hedges	Intensify/contrast/dilate	*Concentration/dilation*	between two hedges value range

Example Let A be a fuzzy set in U, then *very* A is defined as a fuzzy set in U with the membership function

$$\mu_{veryA}(x) = [\mu_A(x)]^3 \tag{3}$$

and the *usually* A is a fuzzy set in U with the membership function

$$\mu_{usuallyA}(x) = [\mu_A(x)]^{1/2} \tag{4}$$

Hence, let $U = \{X_1, X_2, X_3, X_4, X_5\}$ and the fuzzy set *important* be defined as

$$Important = 1/X_1 + 0.7/X_2 + 0.5/X_3 + 0.3/X_4 + 0.1/X_5$$

Then, according to Eq. (3) and Eq. (4), we have

$$Very\ important = 1/X_1 + 0.343/X_2 + 0.125/X_3 + 0.027/X_4 + 0.003/X_5$$

$$Usually\ important = 1/X_1 + 0.837/X_2 + 0.707/X_3 + 0.548/X_4 + 0.316/X_5$$

Table 2: Linguistic Variables and its TFN Values

Linguistic expressions	TFNs
Very high (*VH*)	(0.9,1.0,1.0)
High (*H*)	(0.7,0.9,1.0)
Medium high (*MH*)	(0.5,0.7,0.9)
Medium (*M*)	(0.3,0.5,0.7)
Medium low (*ML*)	(0.1,0.3,0.5)
Low (*L*)	(0,0.1,0.3)
Very low (VL)	(0,0,0.1)

3 The Approach Towards the Proposed Method

In this section, we provide a six step procedure of the proposed method based on the problem situation and basic concepts from the Section 1 and 2, respectively.

Step 1: The actual problems are transformed into a hierarchy structure. Obviously, the structure has at least three levels of hierarchy which comprises of the objective or goal of the study, criteria and sub-criteria, and the alternative at the first, second and third level, respectively.

Step 2: The performance score of the criteria can be obtained by summing-up each of the sub-criteria corresponding to its criteria. In order to deal with the variety of the input datasets (i.e., quantitative and qualitative), two methods were employed.

i. the fuzzy linguistic - it utilised Table 2 to derive its quantitative values corresponding to the triangular fuzzy numbers (TFN).

ii. the input data purely in crisp form - the membership function was constructed after consulting the expert's opinion, while for the data in TFN form, the unifying process is needed to preserve the property in the ranges of [0,1] using Eq. (5) – (7).

$$\bar{R}_i = \left(\tilde{k}_{ij}\right)_{m\times n} \tag{5}$$

$$\tilde{k}_{ij} = \left(\frac{x_{ij}}{M}, \frac{y_{ij}}{M}, \frac{z_{ij}}{M}\right); \quad i = 1, 2, \ldots, n; \text{ and } M = \max_j c_{ij}, \quad j \in \omega_1 \tag{6}$$

$$\tilde{k}_{ij} = \left(\frac{N - z_{ij}}{N}, \frac{N - y_{ij}}{N}, \frac{N - x_{ij}}{N}\right); \quad i = 1, 2, \ldots, n; \text{ and } N = \max_i c_{ij}, \quad j \in \omega_2 \tag{7}$$

ω_1 is a set of benefit-criteria, where the higher the value of $\tilde{k}_{ij}$ the better it is for DM, and ω_2 is a set of cost-criteria, where the lower the value of $\tilde{k}_{ij}$ the better it is for the DM.

Step 3: Assume that a DM has S persons, then the importance of the criteria and the rating of alternatives with respect to each criterion can be calculated as

$$\tilde{a}_{ij} = \frac{1}{S}\left[\tilde{a}^1_{ij}(+)\,\tilde{a}^2_{ij}(+)...(+)\,\tilde{a}^S_{ij}\right] \tag{8}$$

$$\tilde{W}_j = (\mu_{dil/con\;A}(x))^n \tag{9}$$

where $\tilde{a}^S_{ij}$, $\tilde{w}^S_j$ are the rating and the importance weight of the S^{th} stakeholders, respectively, and $n = \left(\alpha^1, \alpha^2, ..., \alpha^k\right)$ is a power of *dilation* or *concentration* of k criteria (Definition 2).

Step 4: Construct the fuzzy multi-criteria decision matrix that is concisely expressed as:

$$\tilde{D} = \begin{array}{cc} & \begin{matrix} C_1 & C_2 & \ldots & C_n \end{matrix} \\ \begin{matrix} A_1 \\ A_2 \\ \ldots \\ A_m \end{matrix} & \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \ldots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \tilde{a}_{22} & \ldots & \tilde{a}_{2n} \\ \ldots. & .. & \ldots & \ldots \\ \tilde{a}_{m1} & \tilde{a}_{m2} & \ldots & \tilde{a}_{mn} \end{bmatrix} \end{array}, \tag{10}$$

where A_1, A_2, $\ldots$, A_m are possible alternatives, C_1, C_2, $\ldots$, C_n are criteria with which performance of alternatives are measured using linguistic variables. These linguistic variables can be describe by triangular fuzzy number, $\tilde{a}_{ij} = \overset{,}{(}x_{ij}\, y_{ij}, z_{ij})$.

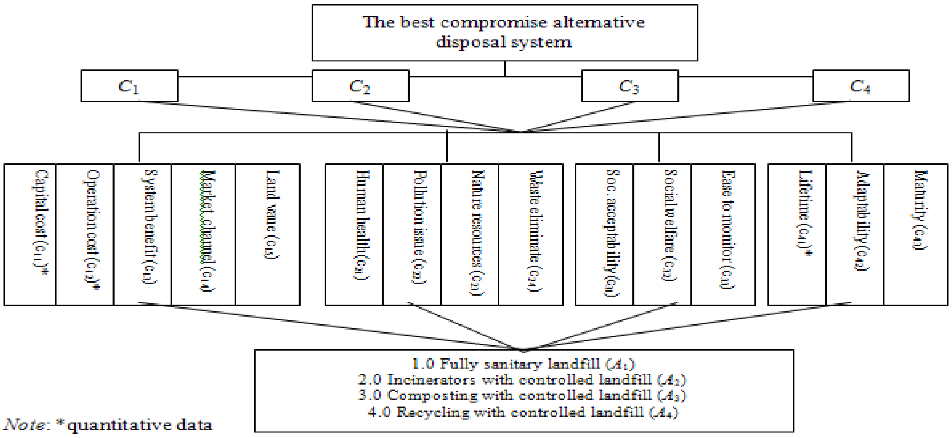
Step 5: Determine the power of *dilation* and/or *concentration* for each criterion and aggregate the DMs opinion denoted as

$$\tilde{D}_H = \begin{pmatrix} \mu_{11}^{(n_1)} & \mu_{12}^{(n_2)} & \ldots & \mu_{1j}^{(n_n)} \\ \mu_{21}^{(n_1)} & \mu_{22}^{(n_2)} & \ldots & \mu_{2j}^{(n_n)} \\ \ldots & \ldots & \ldots & \ldots \\ \mu_{i1}^{(n_1)} & \mu_{42}^{(n_2)} & \ldots & \mu_{ij}^{(n_4)} \end{pmatrix} \tag{11}$$

The average aggregated importance of *dilation* and/or *concentration* for the first criteria (C_1) for instance, can be calculated as $n_1 = (w_1 + w_2 + w_3)/k$, where k is a number of DMs. Similarly, the values of n_2, n_3, … n_k for each criterion (C_i) can be obtained, respectively.

Step 6: Let $\mu_{ij}^{n_i} = (x_i, y_i, z_i), (i = 1, 2, 3, ...m; j = 1, 2, 3, ..., n)$ is positive arbitrary of the TFNs. Thus, the best alternative can be determined using the defuzzification process [9] by choosing the maximum of the crisp value over all the criteria given as

$$\bar{G}_i = \frac{(x_i + y_i + y_i + z_i)}{4}; (i = 1, 2, ..., n) \tag{12}$$



Note: *quantitative data

Figure 2: The Hierarchical Structure of MSW Disposal Alternatives

4 Application via a Case Study

For application purposes, a similar case study conducted by Zamali et al. [11] was adopted. The amount of MSW generations in the state of Selangor and KLFT tremendously increased in line with the population and economic growth, and the existing disposal systems (i.e., traditional landfilling and open dumping) cannot absorb the continuously increasing MSW generation. Thus, the federal government plans to allocate a huge amount for budgeting of the new MSW disposal system. Four possible disposal systems with controlled landfills, $\{A_1, A_2, A_3, A_4\}$ may be considered: A_1 is a fully sanitary landfill; A_2 is an incinerator-equipped waste-to-energy facility with controlled landfill; A_3 is a composting facility with controlled landfill; and A_4 is material recycling with controlled landfill. For these options, four main criteria should be considered; $\{C_1, C_2, C_3, C_4\}$: C_1 is the economic factors; C_2 is the environmental impacts; C_3 is the social impact; and C_4 is the technology used by the systems. Three groups of stakeholders (i.e., each group comprises of at least three persons) are involved and give their assessment based on their expertise and experiences. The finalised evaluation for each group represents the mutual consensus between them. The stakeholders are from government agencies (s^1), experts (s^2), and non-governmental organisations (s^3).

Based on Section 3, the computational procedures are given as follows:

Step 1: Decompose the problem (identify goal, criteria, sub-criteria, alternatives) and construct the hierarchy structure as shown in Figure 2.

Step 2: Calculate the performance score (weights) for each criteria and sub-criteria from the original judgment in *Appendix A*. For attributes c_{11} and c_{41} a unifying process is needed, while for attribute c_{12} the membership function is utilised as shown in Table 3.

Table 3: Crisp Data for Operating Costs (c_{12}) for Each System

Item (c_{12})	A_1	A_2	A_3	A_4	Membership function
Operating costs (RM/tonne)	150	125	187.5	737.5	$\mu_{oc} = \begin{cases} (900-x)/1000, & 100 \leq x \leq 800 \\ 1\,, & x < 100 \end{cases}$

Step 3: Assess the three stakeholders (s^i; i= 1,2,3) that have the following weights; $s^1 = 1/2$, $s^2 = 1/3$and $s^3 = 1/6$, and $\sum_{i=1}^{3} s^i = 1$. Then, calculate the total aggregated score for each of the stakeholders and the results obtained are shown in Table 4 – Table 6, respectively.

Table 4: Fuzzy Aggregated Decision Matrix for s^1

	DM (s^1) 0.5			
	A_1	A_2	A_3	A_4
C_1	(0.3962,0.4792,0.5808)	(0.4350,0.5227,0.5904)	(0.3656,0.5025,0.6363)	(0.3725,0.4940,0.6217)
C_2	(0.350,0.550,0.7250)	(0.550,0.7250,0.850)	(0.350,0.550,0.750)	(0.70,0.850,0.9250)
C_3	(0.4333,0.6333,0.80)	(0.1333,0.30,0.50)	(0.1333,0.30,0.50)	(0.5667,0.7667,0.90)
C_4	(0.70,0.7778,0.80)	(0.60,0.7556,0.9111)	(0.2222,0.3778,0.5333)	(0.3556,0.5444,0.7333)

Step 4: Construct the fuzzy multi-criteria decision matrix the importance of the criteria and the rating of alternatives with respect to each criterion. Meanwhile, the weighted-fuzzy performance matrix can be calculated and the results are shown in Table 7.

Step 5: Aggregate the DMs opinions and determine the power of *dilation* or *concentration* for each criterion based on Table 8. Thus, the weighted-fuzzy performance matrix with importance hedge can be calculated by using Eq. (11) and the results are shown in Table 9.

Step 6: Determine the best alternative by defuzzification process using Eq. (12). The maximum in each alternative can be obtained as A_1 = 0.3036, A_2= 0.3416, A_3 = 0.2647, and A_4 = 0.4761, respectively. The ranking is $A_4 > A_2 > A_1 > A_3$, thus A_4 (i.e., recycling with controlled landfill) is the best choice due to its maximum values among all comparative alternatives.

Table 5: Fuzzy Aggregated Decision Matrix for s^2

	$DM\ (s^2)$ 0.3333			
	A_1	A_2	A_3	A_4
C_1	(0.3562,0.4392,0.5408)	(0.4950,0.6227,0.7104)	(0.6456,0.7825,0.8763)	(0.5325,0.6440,0.7417)
C_2	(0.10,0.250,0.450)	(0.5500,0.7250,0.8500)	(0.30,0.50,0.70)	(0.350,0.550,0.750)
C_3	(0.2000,0.3667,0.5667)	(0.2333,0.4333,0.6333)	(0.3667,0.5667,0.7667)	(0.70,0.8333,0.90)
$\boldsymbol{C_4}$	(0.6333,0.7444,0.80)	(0.6667,0.8222,0.9444)	(0.0889,0.1778,0.3333)	(0.6889,0.8778,1.0)

Table 6: Fuzzy Aggregated Decision Matrix for s^3

	$DM\ (s^3)$ 0.1667			
	A_1	A_2	A_3	A_4
C_1	(0.3162,0.3792,0.5008)	(0.1750,0.2227,0.3104)	(0.4256,0.5225,0.6363)	(0.5325,0.6540,0.7417)
C_2	(0.0750,0.1250,0.250)	(0.1750,0.2250,0.3250)	(0.2750,0.4500,0.650)	(0.40,0.60,0.7750)
C_3	(0.3333,0.4667,0.6333)	(0.0,0.0,0.10)	(0.70,0.90,1.0)	(0.4333,0.6333,0.80)
C_4	(0.2333,0.3778,0.5333)	(0.50,0.5556,0.6444)	(0.3222,0.4444,0.5667)	(0.4222,0.6111,0.80)

Table 7: The Weighted-fuzzy Performance Matrix

Criteria	A_1	A_2	A_3	A_4
C_1	(0.3695,0.4492,0.5541)	(0.4117,0.5060,0.5837)	(0.4689,0.5992,0.7163)	(0.4525,0.5740,0.6817)
C_2	(0.2208,0.3792,0.5542)	(0.4875,0.6417,0.7625)	(0.3208,0.5167,0.7167)	(0.5333,0.7083,0.8417)
C_3	(0.3389,0.5167,0.6944)	(0.1444,0.2944,0.4778)	(0.3056,0.4889,0.6772)	(0.5889,0.7667,0.8833)
C_4	(0.60,0.70,0.7556)	(0.6056,0.7444,0.8778)	(0.1944,0.3222,0.4722)	(0.4778,0.6667,0.8333)

Table 8: The Importance Hedge for Each Criteria

Criteria	Stakeholders/DMs		
	s^1	s^2	s^3
C_1	*Very important*	*Very important*	*Very important*
C_2	*Important*	*Positively important*	*Very important*
C_3	*Positively important*	*Important*	*Positively important*
C_4	*Somewhat important*	*Very important*	*Somewhat important*

Table 9: The Weighted-fuzzy Performance Matrix with Importance Hedge

Criteria	Hedge (n)	A_1	A_2	A_3	A_4
C_1	3	(0.0504,0.0907,0.1701)	(0.0698,0.1296,0.1989)	(0.1031,0.2151,0.3676)	(0.0927,0.1892,0.3169)
C_2	2	(0.0488,0.1438,0.3071)	(0.0488,0.1438,0.3071)	(0.1029,0.2669,0.5136)	(0.2844,0.5017,0.7084)
C_3	5/3	(0.1647,0.3327,0.5446)	(0.0398,0.1303,0.2920)	(0.1386,0.3034,0.5158)	(0.4137,0.6422,0.8132)
C_4	4/3	(0.5061,0.6215,0.6882)	(0.5123,0.6747,0.8405)	(0.1126,0.2209,0.3677)	(0.3735,0.5824,0.7840)

5 Conclusion

In this paper, we have proposed the AHP-based linguistic variable weights for selecting a MSW disposal options. The approach has great potential to deal with the complexity of the decision-making environment. Specifically, the linguistic hedges concept utilised is efficient to deal with the uncertainty of the initial information. It shows that to be very practical and user friendly in the sense that the DMs can easily evaluate all the attributes using the linguistic expressions. Moreover, the method also involves intuition which considers the human rethinking-model using the linguistic expression as an evaluation mechanism for tracking subjectivity. Although the method is seldom utilised by researchers, it is very significant and useful in decision-making environment due to its effectiveness, simplicity and systematic manner of approach.

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Appendix A

The importance weights of all criteria and sub-criteria from three stakeholder's perspectives

	Item	A_1			A_2			A_3			A_4		
		s^1	s^2	s^3	s^1	s^2	s^3	s^1	s^2	s^3	s^1	s^2	s^3
	Economic (C_1)												
c_{11}	Capital cost (*in RM billion*)	(0.95,1.0, 1.10)			(6.0, 6.25, 6.50)			(1.50, 1.95, 2.5)			(1.0, 1.25, 1.30)		
c_{12}	Operation cost (*in RM/tonne*)	150			125			187.5			737.5		
c_{13}	System benefit	*ML*	*ML*	*L*	*H*	*H*	*VL*	*M*	*H*	*MH*	*M*	*H*	*H*
c_{14}	Market channel	*M*	*ML*	*L*	*H*	*H*	*VL*	*ML*	*H*	*M*	*ML*	*H*	*M*
c_{15}	Land value	*VL*	*VL*	*L*	*VL*	*M*	*ML*	*ML*	*MH*	*VL*	*MH*	*M*	*H*
	Environmental(C_2)												
c_{21}	Human health	*ML*	*M*	*VL*	*M*	*M*	*VL*	*ML*	*M*	*L*	*VH*	*MH*	*H*
c_{22}	Pollution issue	*ML*	*L*	*VL*	*M*	*M*	*VL*	*MH*	*M*	*M*	*H*	*M*	*M*
c_{23}	Nature resource	*H*	*L*	*VL*	*VH*	*H*	*VL*	*M*	*M*	*M*	*VH*	*MH*	*MH*
c_{24}	Waste elimination	*MH*	*ML*	*M*	*H*	*VH*	*H*	*MH*	*M*	*MH*	*M*	*ML*	*ML*
	Social (C_3)												
c_{31}	Social acceptability	*H*	*M*	*MH*	*M*	*M*	*VL*	*ML*	*M*	*H*	*H*	*VH*	*M*
c_{32}	Social welfare	*MH*	*M*	*MH*	*ML*	*M*	*VL*	*L*	*M*	*H*	*M*	*VH*	*M*
c_{33}	Ease to admin/ monitoring	*ML*	*L*	*VL*	*L*	*ML*	*VL*	*M*	*MH*	*H*	*H*	*M*	*H*
	Technological (C_4)												
c_{41}	Lifetime (*in year*)	(9, 10, 12)			(18, 20, 25)			(8, 10, 12)			(20, 25, 30)		
c_{42}	Adaptability	*VH*	*H*	*M*	*H*	*H*	*VH*	*M*	*L*	*H*	*M*	*H*	*M*
c_{43}	Maturity	*VH*	*VH*	*ML*	*MH*	*H*	*VL*	*ML*	*L*	*L*	*ML*	*H*	*M*

Notes: RM is Ringgit Malaysia, US$1 = RM3.50(approx.)

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