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Research article

Application of TOPSIS and VIKOR improved versions in a multi criteria decision analysis to develop an optimized municipal solid waste management model

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ABSTRACT

Selecting a suitable Multi Criteria Decision Making (MCDM) method is a crucial stage to establish a Solid Waste Management (SWM) system. Main objective of the current study is to demonstrate and evaluate a proposed method using Multiple Criteria Decision Making methods (MCDM). An improved version of Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) applied to obtain the best municipal solid waste management method by comparing and ranking the scenarios. Applying this method in order to rank treatment methods is introduced as one contribution of the study. Besides, Viekriterijumsko Kompromisno Rangiranje (VIKOR) compromise solution method applied for sensitivity analyses. The proposed method can assist urban decision makers in prioritizing and selecting an optimized Municipal Solid Waste (MSW) treatment system. Besides, a logical and systematic scientific method was proposed to guide an appropriate decision-making.

A modified TOPSIS methodology as a superior to existing methods for first time was applied for MSW problems. Applying this method in order to rank treatment methods is introduced as one contribution of the study. Next, 11 scenarios of MSW treatment methods are defined and compared environmentally and economically based on the waste management conditions. Results show that integrating a sanitary landfill (18.1%), RDF (3.1%), composting (2%), anaerobic digestion (40.4%), and recycling (36.4%) was an optimized model of integrated waste management. An applied decision-making structure provides the opportunity for optimum decision-making. Therefore, the mix of recycling and anaerobic digestion and a sanitary landfill with Electricity Production (EP) are the preferred options for MSW management.

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1. Introduction

One of the most crucial issues in environment protection and natural resources conservation is waste management. Various methods can be applied to manage the solid waste. Biological treatment, thermal treatment, and landfilling are the common ways for disposal of solid waste (Seng et al., 2011; Yildirim, 2012).

Moreover, Hamid (2010) in a study calculated the percentages of waste managed in Malaysia considering the population in 2010 and the waste production of 0.9 kg/capita. It was reported that, Municipal Solid Waste (MSW) in Malaysia includes of food waste 42%, plastics 17%, glass 3%, paper 15%, and metal 3%. Results showed that the waste production are going to be increased to the value of 1.7 kg/day for each person in the main cities (Hamid, 2010).

It was illustrated that depending on many specific factors

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related to the country's condition, the problem of MSW management in Malaysia is complex (Vego et al., 2008). Selecting the best MSW treatment method in terms of environmental quality and economic benefit is an important goal for Malaysian decision makers. To address the issue, effective technology systems must be evaluated using (MCDM) tools considering future development and the sustainability of the environment.

The application of decision-making using MCDM method in the field of solid waste management in Malaysia is still limited (Zamali and Mohd, 2010; Abushammala, et al., 2011). The results of different studies show that this method has the potential to handle the uncertainty of datasets, and decision makers can easily evaluate attributes using linguistic expressions (Carlsson and Walden, 1995; Bahraminasab and Jahan, 2011; Dehghan et al., 2007).

Ekmekçioğlu et al. (2010) and Zhang and Huang (2014) used MCDM to select an appropriate waste disposal method. It was focused on the last disposal stage of MSW, the proposed method showed that any municipality should select the most appropriate method to manage the solid waste. A comparison of solid waste disposals based on the possible alternatives showed that RDF combustion is the best method as an alternative for MSW at Istanbul, Turkey.

Regarding the economic aspect, Hassan et al. (2000) conducted a study to compare the direct costs and benefits of three waste management systems including landfills, incinerators, and RDF. The results showed that the cost of operating RDF was much lower than the incineration in the Beroga area (both with and without the cost of financing) and Labuan island in Malaysia.

The current study is an attempt to improve selecting the optimal disposal options for generated waste, develop an appropriate methodology for future decision-making that combines the diverse issues involved in prioritising MSW management systems considering economic and environmental aspects.

2. Methodology

2.1. Evaluation of the selected methods

Recent studies employed several Multiple Criteria Decision Making (MCDM) methods in correlation with weighted averages, priority setting, outranking, fuzzy principles, or a combination of those parameters for waste management planning decisions (Li and Chen, 2011; Macharis et al., 2004; Pohekar and Ramachandran, 2004). The simple approach is to identify several alternatives. The evaluation of the selected methods in terms of the criteria is the most important activity in developing the scenarios. Regarding a MCDM and Life Cycle Assessment (LCA), decision models are applied mostly in recent years (Su et al., 2010). The most feasible solution for MSW problems is a good performance compared with the other alternatives that has similar priorities (Kum et al., 2005).

One of the main steps of multi criteria decision making are developing alternative systems for attaining the goals and applying a normative multi criteria analysis method such as TOPSIS and VIKOR.

Furthermore, a research carried out to evaluate solid waste treatment technology in Malaysia to achieve a better planning in order to develop the efficiency and usefulness of solid waste management. MCDM model applied in order to selection of a suitable solid waste treatment method. The finding of the study showed that the combination of recycling and composting technology is the most appropriate solid waste treatment technology for the area.

In contemporary models such as those based on MCDM, the objective aims for promoting a compromise between different priorities as a solution is calculated. The most feasible solution is the one that performs well against all other alternatives when compared with the same set of priorities. The inconsistencies between the actual scenario and the ideal conditions are outlined as the preference weights of the different criteria. This method focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. It introduces the multi-criteria ranking index based on the particular measure of "closeness" to the "ideal" solution (Opricovic and Tzeng, 2004). VIKOR is a helpful tool particularly in a situation where the decision maker is not able, or does not know to express his/her preference at the beginning of system design. In order to do sensitivity analysis the VIKOR method has been applied here. This method had been developed for the multi-criteria optimisation of complex systems (Bahraminasab and Jahan, 2011) and is widely used today. It focuses on ranking and selecting among alternatives with conflicting criteria with different units. In the VIKOR approach, compromise ranking is performed by comparing the measurement of each alternative's closeness to the ideal alternative, and compromise entails an agreement established by mutual concessions while, TOPSIS as a novel technique has been proposed for both objective and subjective weighting of criteria which is modified digital logic method. The new numerical method is proposed as a new Digital Logic (DL) which evaluates and organizes objective and subjective (Dehghan et al., 2007).

The information that is needed to establish an appropriate model for MSW treatment in Malaysia can be obtained from a variety of sources, including experts, literature, and information on the LCA of waste management, as well as field observations. Global warming as an environmental criterion are considered and cost as an economic criterion in establishing an appropriate model. In addition, qualitative criteria defined on the basis of expert interviews were considered. Fig. 1 shows the flow chart of the methods used in the current study.

2.2. Defining criteria and alternatives

The environmental, economic, and social decision-making perspective requires MCDM estimation models based on quantitative data and qualitative value judgments. Furthermore, based on LCA procedure defining different scenarios based on the actual condition of MSW management is beneficial to compare and achieve the proper overview to obtain the clear assessments of MSW management methods through scenarios (Agamuthu and Fauziah, 2011). Besides, a communication considering actual condition of MSW management was done with experts of the Nuclear Agency and National Department of Solid Waste Management of Malaysia. Results of the communications led us to make the 11 scenarios for following analyses.

The main method of solid waste management is currently landfilling, which accounts for 82.3% of the solid waste generated. Most landfill sites are open dumping areas. Sanitary landfills treat 7.8% of waste, RDF 3.1%, and composting 2%, while incineration also plays a role.

In order to obtain the value of environmental criteria, results of the inventory analyses in LCA have been applied. However, although CH_4 is accounted for in the estimation of GHG emissions from solid waste management practices, CO_2 is not, despite its known global warming potential upon release. This discrepancy is due to the general consensus that CO_2 from waste decomposition is of biogenic origin and hence does not add to the overall GHG emissions that solid waste management contributes to the atmosphere (Manfredi and Christensen, 2009). In order to measure CH_4 emission for landfill, Land Gem software has been applied (Abushammala et al., 2011). The reference substance for global warming is carbon dioxide. All greenhouse gases are expressed in a unit of kg CO_2 equivalents per ton MSW treated.

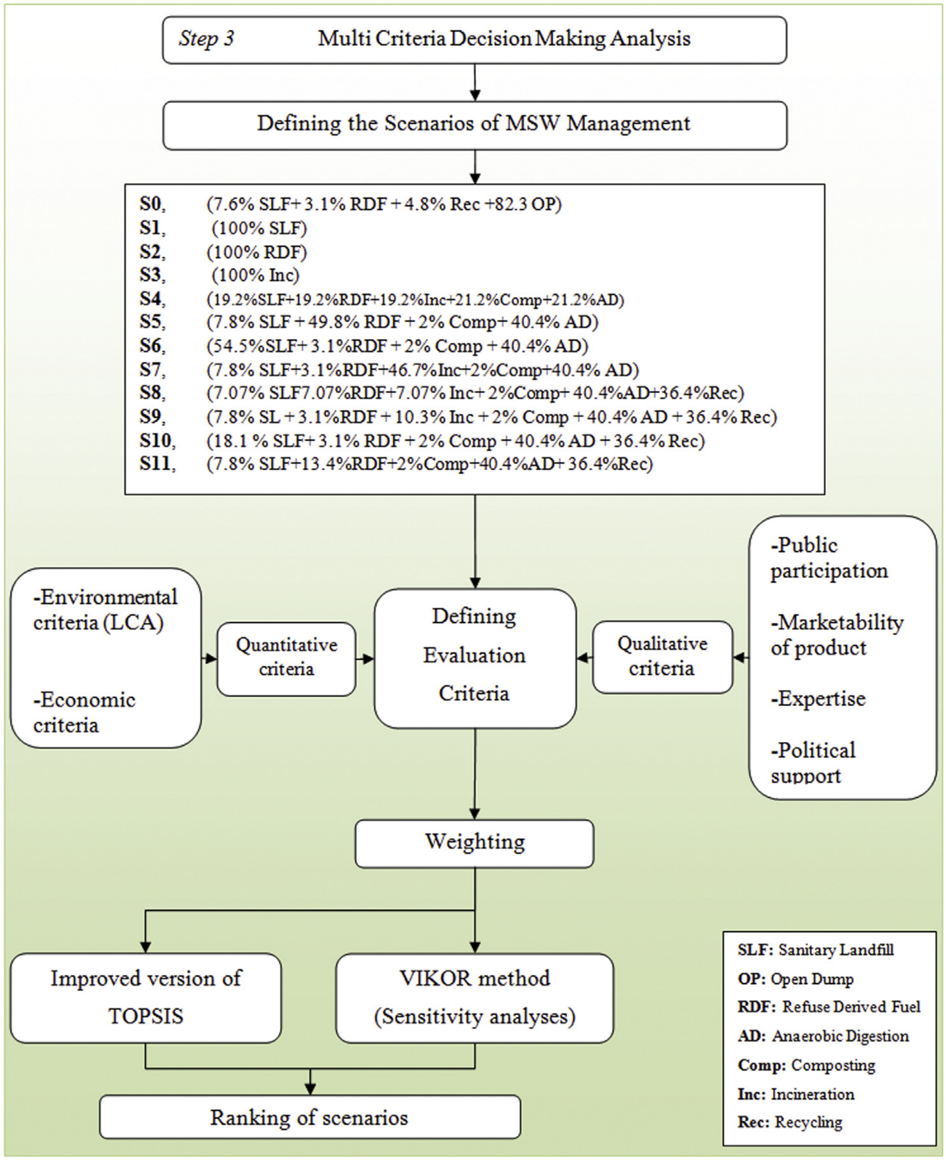

Fig. 1. Summary of multi criteria decision making steps.

The equivalency factor for potential contributions from greenhouse gases to global warming over a time horizon of 100 years is 1 for carbon dioxide, 2 for carbon monoxide, 23 for methane, and 296 for nitrous oxide (Manfredi and Christensen, 2009). So, these reference substances make GHG emissions to be normalised and comparable. However, they have been compared based on CO_2 equivalents. Furthermore, different waste treatment alternatives have been considered to obtain the values of 2 economic sub-criteria (initial investment and operation cost) by measuring actual data from Malaysian plants.

2.3. Theoretical considerations for method development

A matrix format including possible alternatives$A_i(i=1,\ldots,m)$ can express MCDM problem with finite possibilities from which decision makers should select criteria$c_j(j=1,\ldots,n)$, the relative standing of criteria (or weights)w_j, and elements x_{ij}, that rate alternative i with respect to criterion j.

Available *weighting methods* in defining criteria importance are categorised into three groups. First group includes subjective methods, where the importance of the criteria is assigned by the Decision Maker (DM). Objective methods are included in the second group, where the DM is not considering determining the importance of the criteria. The in the third group, a weighting scheme combines the two previous methods (Jahan et al., 2012a,b). In the objective methods weights are obtained based on the data of the recognized problem. These methods are particularly appropriate for situations with unavailable reliable subjective weights. In subjective weighting, a pair-wise comparison is a popular technique where participants are enquired to compare the criteria importance at the same time (Leung and Cao, 2000).

The Modified Digital Logic Approach (MDL) as a subjective method as well as an objective method; namely, standard deviation is used here to find the weights, or criteria importance (Jahan et al., 2012a,b; Dehghan et al., 2007). These weights are combined according to Equation (1) (Bahraminasab and Jahan, 2011).

$$W_j = w_j^o \lambda + w_j^s (1 - \lambda) \quad j = 1, 2, 3, \ldots, n \tag{1}$$

where, w_j^o and w_j^s are the objective and subjective weights, respectively ($0 \le \lambda \le 1$). It should be considered that $\sum_{j=}^{n} W_j$ is equal to 1 in Equation (1) as $\sum_{j=1}^{n} w_j^o = 1$, $\sum_{j=1}^{n} w_j^s = 1$ and $\lambda + (1 - \lambda) = 1$. Changing the value of λ between 0 and 1 allows sensitivity analysis of the weights.

TOPSIS considers that the distance of the optimum point is the furthest from the Negative Ideal Solution (NIS) where it has the shortest distance from the Positive Ideal Solution (PIS), making this method suitable for risk-avoidance designs. Therefore, TOPSIS is a reliable method for risk-avoidance because the designers may desire a decision that not only maximises profit but also avoids risk. Following are the steps for the extended version of TOPSIS (Jahan et al., 2012a,b).

Convert the raw measures x_{ij} into standardised measures r_{ij} according to the proposed normalisation technique in Equation (2).

i.

$$\mathbf{r_{ij}} = \mathbf{1} - \frac{\left|\mathbf{x_{ij}} - \mathbf{T_j}\right|}{\mathbf{Max}\left\{\mathbf{x_{ij}^{max}}, \mathbf{T_j}\right\} - \mathbf{Min}\left\{\mathbf{x_{ij}^{min}}, \mathbf{T_j}\right\}} \tag{2}$$

ii. Develop a set of importance weights w_j for the existing criteria.

iii. Multiply the values in columns of the normalised decision matrix by the corresponding weights (Equation (3)).

$$V_{ij} = r_{ij} w_j; \; j = 1, 2, 3, \ldots, n; \; i = 1, 2, 3, \ldots, m \tag{3}$$

iv. Identify the PIS (Equation (4)).

$$\left\{V_1^+, V_2^+, V_3^+, \ldots, V_n^+\right\} = \left\{\left(\underset{i}{Max}\, V_{ij} \middle| i = 1, \ldots, m\right\}\right. \tag{4}$$

v. Detect the NIS (Equation (5)).

$$\left\{V_1^-, V_2^-, V_3^-, \ldots, V_n^-\right\} = \left\{\left(\underset{i}{Min}\, V_{ij} \middle| i = 1, \ldots, m\right\}\right. \tag{5}$$

vi. Develop a distance measurement of the alternatives for both of the least ideal (D^-) ideal (D^+) and values by Equations (5) and (6).

$$D_i^+ = \left(\sum_{j=1}^{n}\left(V_{ij} - V_j^+\right)^2\right)^{0.5} \quad i = 1, 2, 3, \ldots m; \; \text{and} \; D_i^- = \left(\sum_{j=1}^{n}\left(V_{ij} - V_j^-\right)^2\right)^{0.5} \quad i = 1, 2, 3, \ldots m \tag{6}$$

vii. Calculate the comparative closeness to the ideal solution using Equation (7).

$$C_i = \frac{D_i^-}{D_i^- + D_i^+}; \; i = 1, 2, 3, \ldots m; \; 0 < C_i < 1 \tag{7}$$

viii. Rank the alternative solutions by maximising the obtained ratios (step vii). The larger the index value, the better the alternative's performance. Table 1 illustrates the difference between an improved version of TOPSIS, which is used in this study, and the original TOPSIS method (Jahan et al., 2012a,b).

Furthermore, in an assessment of WMS according to the economic aspect by Hassan et al. (2000), it was illustrated that the cost of an open dump was minimal within the range of RM 10 to RM 15 per ton at 2004 prices. Furthermore, the cost of investing in an open dump was calculated of $74/ton/year (Hamid, 2010). Land cost was assumed to be zero because it was normally provided by the government at no cost (Hassan et al., 2000).

The VIKOR method was established for the multi-criteria optimisation of complex systems (Bahraminasab and Jahan, 2011; Opricovic and Tzeng, 2004). VIKOR is a helpful tool, particularly in a condition that the preference is unknown for a decision maker at the beginning of the system design. Computation of the optimum point based on the point's closeness to the PIS makes VIKOR suitable for obtaining maximum yield.

The VIKOR procedure has the following steps:

Step 1. Determine the best and the worst values of all criterion
Step 2. Compute the values by the relations, weighted and normalized distance and expressing preference as the relative importance of the criteria.
Step 3. Compute the values by the relation and is introduced as a weight for the strategy of maximum group utility.
Step 4. Rank the alternatives, sorting by the values from the minimum value.
Step 5. Propose as a compromise solution the alternative which is the best ranked by the measure if the following two conditions are satisfied (Mohamed, 2012).

The model applied in this study helps decision makers to recognize the various complexities of SWM problems to accomplish at an effective disposal method.

3. Results, discussion, and method development

3.1. Results

Waste management alternatives are considered for obtaining the values of two economic sub-criteria, including initial investment and operation cost by measuring actual data from Malaysian plants. Qualitative criteria, including political support, technical experts, marketability of products and public participation/awareness applied for ranking. Environmental criteria of scenarios has been measured by LCA. And, qualitative criteria has been considered by questionnaire. The interview has been applied with the experts to find out the ideas related to the problem of waste management and their suggestion regarding the improvement of existing condition to develop a framework for municipal solid waste management.

Therefore, the interview attempts to improve the condition of municipal solid waste management considering appropriate methods for future decision making that combines the diverse issues involved in prioritising MSW management scenarios. These problems have been considered by Life Cycle Assessment (LCA) method in order to find out the potential impacts of different waste management methods and Multi Criteria Decision Making (MCDM). Modelling framework, enables addressing each aspect of a complex problem in a systematic manner. The model assists in identifying a more holistic solution and provides insight into a preferable municipal waste management alternative.

Table 1
The differences between improved version and original TOPSIS method.

Steps	Improved version of TOPSIS	Original TOPSIS
Step 1	Convert the raw measures x_{ij} into the standardized measures r_{ij}, Where T_j is either the most favorable element (x_{ij}) or the target value in criteria j. $r_{ij} = 1 - \frac{\lvert x_{ij} - T_j \rvert}{Max\{x_{ij}^{max}, T_j\} - Min\{x_{ij}^{min}, T_j\}}$	Converting raw measures x_{ij} into standardized measures r_{ij} $r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}};\ j = 1,2,3,\ldots,n;\ i - 1,2,3,\ldots,m$
Step 2	Multiply the columns of the normalized decision matrix by the associated weights (w_j). $V_{ij} = r_{ij}w_j;\ j = 1,2,3,\ldots,n;\ i = 1,2,3,\ldots,m$	Multiply the columns of the normalized decision matrix by the associated weights (w_j). $V_{ij} = r_{ij}w_j;\ j = 1,2,3,\ldots,n;\ i = 1,2,3,\ldots,m$
Step 3	Identify the positive ideal solution. $\{V_1^+, V_2^+, V_3^+, \ldots, V_n^+\} = \{(\underset{i}{Max}\, V_{ij} \vert\, i = 1,\ldots,m\}$	Identify the positive ideal solution, where K the index is set of benefit criteria and K' is the index set of cost criteria. $\{V_1^+, V_2^+, V_3^+, \ldots, V_n^+\} = \{(\underset{i}{Max}\, V_{ij} \vert j \in K),\ (\underset{i}{Min}\, V_{ij} \vert j \in K') \vert\, i = 1,\ldots,m\}$
Step 4	Identify the negative ideal solution. $\{V_1^-, V_2^-, V_3^-, \ldots, V_n^-\} = \{(\underset{i}{Min}\, V_{ij} \vert\, i = 1,\ldots,m\}$	Identify the negative ideal solution, where K the index is set of benefit criteria and K' is the index set of cost criteria. $\{V_1^-, V_2^-, V_3^-, \ldots, V_n^-\} = \{(\underset{i}{Min}\, V_{ij} \vert j \in K), (\underset{i}{Max}\, V_{ij} \vert j \in K') \vert\, i = 1,\ldots,m\}$
Step 5	Develop a distance measure for each alternative to both ideal (D^+) and nadir (D^-) using following equations: $D_i^+ = (\sum_{j=1}^{n} (V_{ij} - V_j^+)^2)^{0.5} \quad i = 1,2,3,\ldots m$ $D_i^- = (\sum_{j=1}^{n} (V_{ij} - V_j^-)^2)^{0.5} \quad i = 1,2,3,\ldots m$	Develop a distance measure for each alternative to both ideal (D^+) and nadir (D^-) using following equations: $D_i^+ = (\sum_{j=1}^{n} (V_{ij} - V_j^+)^2)^{0.5} \quad i = 1,2,3,\ldots m$ $D_i^- = (\sum_{j=1}^{n} (V_{ij} - V_j^-)^2)^{0.5} \quad i = 1,2,3,\ldots m$
Step 6	Calculate the relative closeness to the ideal solution. $C_i = \frac{D_i^-}{D_i^- + D_i^+};\ i = 1,2,3,\ldots m;\ 0 < C_i < 1$	Calculate the relative closeness to the ideal solution. $C_i = \frac{D_i^-}{D_i^- + D_i^+};\ i = 1,2,3,\ldots m;\ 0 < C_i < 1$
Step 7	Rank alternatives by maximizing the ratio in Step 7. The larger the index value, the better the performance of the alternative.	Rank alternatives by maximizing the ratio in Step 7. The larger the index value, the better the performance of the alternative.

Alternative scenarios were ranked through an improved version of TOPSIS. Original TOPSIS uses vector normalisation that cannot accommodate negative values in the decision matrix. Therefore, we applied an improved version of TOPSIS. Table 2 demonstrates the ranking of the SWM alternatives according to the TOPSIS and VIKOR methods with different weights.

Table 3 shows ranking of different disposal options using VIKOR based on the multi-criteria in the model.

Results showed that integrating recycling and anaerobic digestion was the optimum option for MSW management considering both qualitative and quantitative criteria. The disposal of waste in sanitary landfills that also produces electricity, and a sanitary landfill with EP were the second and third preferred options, respectively. The waste treatment method was not utilised as a waste treatment method because the characteristics of waste made it unsuitable for combustion.

Consequently, using combustion requires installing systems for controlling the environment in which the costs and complexities are equivalent or may higher than a combustion system. Therefore, the major reason for preferring sanitary landfills with EP is the resulting revenue from EP.

A high percentage of organic waste in the area offers a possibility of bioconversion into value added products. Existing waste management generates no revenue but a deficit due to composting, and waste-to-energy conversion due to the lack of recycling and composting.

Several researchers confirmed that incineration was not a suitable option for the country (Agamuthu and Fauziah, 2011;

Table 2
Ranking results using TOPSIS method.

	D+ (ideal solution)	D− (negative ideal solution)	C (closeness to the ideal solution)	Rank
S0 (7.6% SLF + 3.1% RDF + 4.8% Rec + 82.3 LF)	0.252	0.177	0.413	10
S1 (100% SLF)	0.201	0.201	0.500	8
S2 (100% RDF)	0.227	0.200	0.468	9
S3 (100% Inc)	0.298	0.093	0.238	12
S4 (19.2% SLF + 19.2% RDF + 19.2% Inc + 21.2% Comp + 21.2% AD)	0.169	0.195	0.535	7
S5 (7.8% SLF + 49.8% RDF + 2% Comp + 40.4% AD)	0.149	0.246	0.623	6
S6 (54.5% SLF + 3.1% RDF + 2% Comp + 40.4% AD)	0.147	0.247	0.626	5
S7 (7.8% SLF + 3.1% RDF + 46.7% Inc + 2% Comp + 40.4% AD)	0.228	0.154	0.402	11
S8 (7.07% SLF 7.07% RDF + 7.07% Inc + 2% Comp + 40.4% AD + 36.4% Rec)	0.083	0.291	0.778	4
S9 (7.8% SLF + 3.1% RDF + 10.3% Inc + 2% Comp + 40.4% AD + 36.4% Rec)	0.080	0.291	0.783	3
S10 (18.1% SLF + 3.1% RDF + 2% Comp + 40.4% AD + 36.4% Rec)	0.034	0.322	0.904	1
S11 (7.8% SLF + 13.4% RDF + 2% Comp + 40.4% AD + 36.4% Rec)	0.044	0.318	0.877	2

Table 3
Ranking results using VIKOR method.

Scenario no.	S (maximum utility of the majority)	R (minimum individual regret of the opponent)	Q (compromise solution factor)	Rank
S0	0.6387	0.1528	0.859	11
S1	0.5142	0.1319	0.702	10
S2	0.6080	0.1042	0.653	8
S3	0.8650	0.1319	0.920	12
S4	0.4796	0.0819	0.487	5
S5	0.3545	0.1071	0.507	6
S6	0.3318	0.1205	0.544	7
S7	0.6570	0.1042	0.683	9
S8	0.1808	0.0534	0.191	3
S9	0.1820	0.0534	0.192	4
S10	0.0607	0.0231	0.000	1
S11	0.0824	0.0307	0.043	2

Kathirvale et al., 2004; Manaf et al., 2009; Murad and Siwar, 2007; Periathamby et al., 2009; Saeed et al., 2009; Tarmudi et al., 2012). However, the calorific value is reduced drastically if the waste samples are wet. It is attributable to the presence of high moisture content in the waste stream. In addition, it was found that combusting the waste for disposal via incineration was not economical. In addition, RDF conversion was not feasible and cost-effective for the country's waste since source separation was absent, while liquid waste co-mingled in the solid waste. Finally, ranking the different scenarios in the current study showed that RDF still is eligible for landfilling and incineration.

3.2. Method development

SWM in many developing and under-developed nations is generally practiced with an unsustainable approach, and is more economics-oriented. Appropriate SWM planning is unachievable due to the lack of updated and comprehensive data regarding waste composition and generation. Existing disposal sites are quickly filled. This is happening due to lack of proper and effective waste management planning. The high percentage of food waste is mainly due to the lack of alternative routes besides its disposal into the MSW stream.

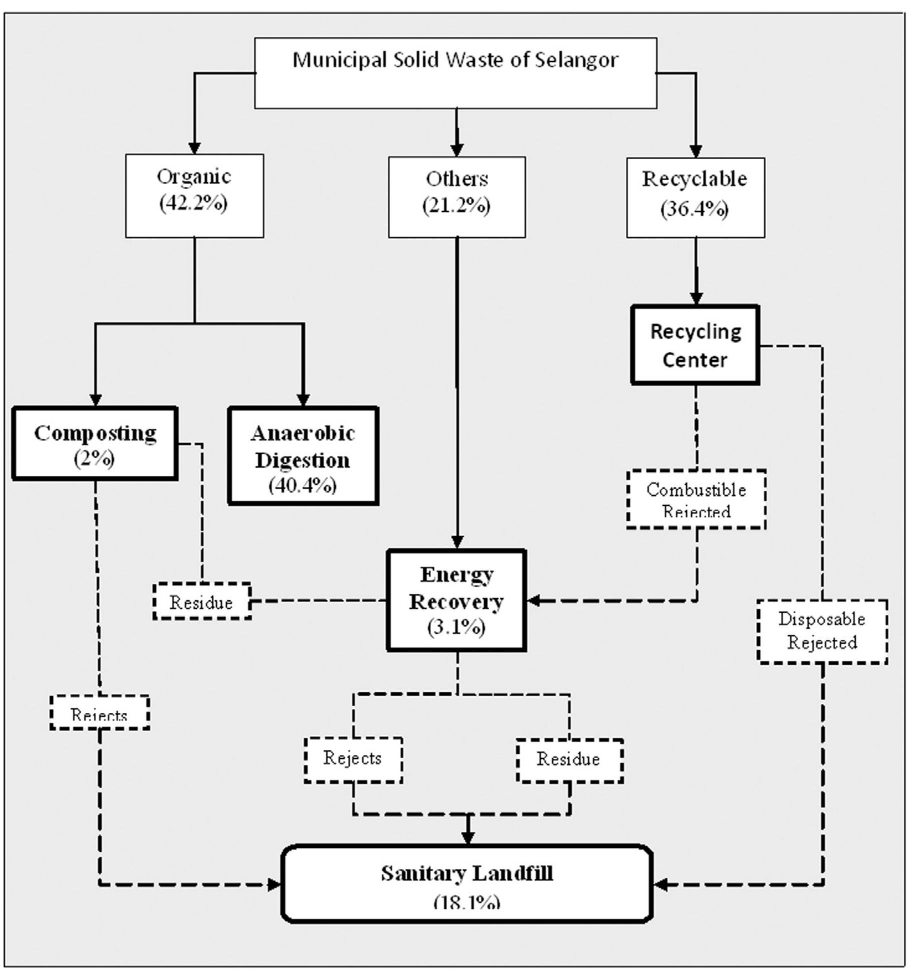

Fig. 2. Proposed framework for integrated MSW management in Malaysia.

Selangor state was selected as the study area due to its rapid development, which represents the future situation for other states in Malaysia. In addition, current waste management practice in Selangor lacks source separation and recycling (Agamuthu and Fauziah, 2011). Fig. 2 shows the integrated Municipal Solid Waste Management (MSWM) system proposed in this study for MSWM.

If the waste management system does not improve, it will waste profuse resources ranging from recyclable materials, combustible components, and degradables in landfills. Regarding the proposed path, the diversion of compostable waste for composting and anaerobic digestion eliminates the total waste generated. Meanwhile, less degradable components including wood, rubber, and other combustible items could be diverted to energy recovery centres. In the future, these portions should be utilised to generate energy for the community. Also, recycling helps to reduce landfill gases particularly CH_4. On the other hand, recyclables could be rerouted for recycling to prevent the loss of valuable materials in landfills. Therefore, recycling is crucial due to the increase in land price and difficulty in finding a suitable area for a landfill site.

4. Conclusion

The current study covers the different municipal waste management methods in this area regarding viability of recycling, composting, (RDF) conversion, and their impacts on the environment for future implementation. It also provides recommendations to waste managers in order to improve waste management systems via a more sustainable approach. Different scenarios of the MSW management methods have been compared and ranked to predict an integrated method for solid waste management. Economics and the environment were the main criteria in the ranking. MCDM methodology and improved version of TOPSIS was used in the ranking. As the original TOPSIS did not convert negative points to positive points in comparison, extra measurements in the residual parts of the algorithm were used. A combination of the TOPSIS and VIKOR methods by sensitivity analysis was applied to the ranking of the scenarios of solid waste management. With the ranking, the most appropriate and the improper scenarios for municipal waste management including were identified. Furthermore, it was proven that current conditions of municipal SWM are not suitable.

The proposed method can be applied as a guideline for a variety of future SWM problems, and similar models can be established to address different environmental problems regarding the SWM. Based on the results, the proposed model can be widely used to the evaluation of various policies related to waste treatment, such as waste reduction, transfer stations for MSW, resource recycling, and decommissioning or implementation of waste treatment facilities.

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Abbreviations

DM	Decision Maker
EP	Electricity Production
GHG	Green House Gas
LandGem	Landfill Gas Emission Model
LCA	Life Cycle Assessment
MCDM	Multi-Criteria Decision Making Analyses
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
NIS	Negative Ideal Solution
PIS	Positive Ideal Solution
RDF	Refuse Derived Fuel
RM	Ringgit Malaysia
SWM	Solid Waste Management
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
VIKOR	Vlsekriterijmska Optimizacija Kompromisno Resenje (in English: Vlsekriterijmska Optimization compromise Solution)

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