Developing Decision on Suitable Wastewater Treatment Technology Using Fuzzy Simple Additive Weighting

Lazim Abdullah [#1]

[#] School of Informatics and Applied Mathematics,
Universiti Malaysia Terengganu 21030 Kuala Terengganu, Malaysia
[1] lazim_m@umt.edu.my

Abstract— As is generally known, water could purify to its natural substances by performing basic wastewater treatment (WWT). Despite many WWT technologies available nowadays, experts have difficulty selecting the most suitable technology due to so many criteria that governed the selection. The paper aims to identify the most suitable WWT technology using the multi-criteria decision making technique, fuzzy simple additive weighting (FSAW). Three decision makers which is knowledgeable in WWT technologies are appointed to evaluate and provide information regarding the WWT technologies and its affiliated criteria. Decision makers were asked to rate the criteria for every WWT technology within the framework of FSAW. The seven-step algorithm of FSAW has successfully identified anaerobic digestion as the most suitable technology in WWT. An implication of these findings is that both potential WWT technologies and criteria should be taken into account when considering the most suitable technology that could bring benefits to community.

Keyword- Wastewater treatment, Decision making, Fuzzy set, Simple additive weighting

I. INTRODUCTION

The past decade has seen the rapid development of economic activities and increase in a country's population. One of the basic infrastructures to deal with a large number of people with a diverse economic activity is treated water. Sustainable treated water infrastructure is essential so that the people will be able to consume clean and safe water. This infrastructure may assist to improvise the environmental, economic and social health of the nation's communities [1]. But nowadays, due to rapid economic growth especially with the mushrooming of industrial activities, most of clean water sources such as river had been affected by their waste product. These waste products which flow into the water source makes the water source turn into wastewater. In order to protect the environment from negative impact of wastewater and also to sustain a healthy life, it is an urgent need to find a good technology that can provide clean treated water. Wastewater treatment (WWT) technology is inevitable despite its highly operating cost and ineffective to the more environmental friendly approaches. Among the popular approaches in WWT technologies are anaerobic digestion, phytoremediation, and composting. Anaerobic digestion is defined as a process which involves the breakdown of biodegradable material by microorganism like bacteria with the absence of oxygen. Phytoremediation is another method of WWT technology. Formally, this term is defined as the process that transforms the modified natural environment to its natural condition through contaminations by microorganisms, fungi, green plants, or their enzyme. Simply, this process may also be said as a treatment of environmental problem through the use of plants [2]. It is originally used to enhance the biodegradation ability of plants. On the other hand, composting is a process that alters the wastewater by decomposition with the presence of enzymes through biological and biochemical process [3]. By controllable condition, the composting of solids from mud is beneficial in providing tools for fertilizer management. It is typically applied in the field of organic farming to enhance the properties of fertilizers [3];[4];[5].

Many technological alternatives for WWT are available nowadays, ranging from advanced technologies to conventional treatment options. It is difficult to select the most appropriate technology from a set of available alternatives to treat wastewater at a particular location. Sustainability criteria must be incorporated into the decision making process. Therefore, selecting the suitable WWT technology is not a straight forward process. There are number of sustainability criteria need to be taken into account. Criteria considered in selecting the suitable WWT technology may include economically (e.g. costs and benefits obtain in using the technology), environmentally (e.g. how its process could harm the surroundings by air emission and water pollution), and technologically (e.g. level of technology applied along the process) [2]. Table 1 shows the simplified form of criteria and sub-criteria that typically take into consideration in selecting the suitable WWT technology.

TABLE 1.
Criteria and its sub-criteria [2]

Criteria	Sub-Criteria	Description
Economic Aspect	Investment Cost	Cost applied to construct the WWT plant.
	Operating Cost	Cost applied to manage the WWT plant.
	Energy Saving	Reuse part of energy process to minimize the total energy cost.
Technological Aspect	System Complexity	Complexity involve in the project in term of required equipment, and authorization and administration difficulties.
	Management Activities	Operative management of WWT plant in term of maintenance, staff needed, monitoring, and external structures.
	Performances	Aspect involve for a good final performance including volume of treated waste, time limitation, and waste degradation.
Environment Aspect	Natural Resources	Natural resource (e.g. water and energy) consumed.
	Visual Impact	Disturbance exists from the construction of the WWT plant.
	Smell Impact	Existence of unwanted smells

The idea behind the use of suitable WWT technology is to keep water in its natural conditions. The selection of technology must fulfil certain criteria in order to make it a good technology and in road of sustainability. It can be seen that selecting the suitable technology that governed by multi criteria is inundated task. It is due to the number of almost equally importance of alternatives and number of multi-conflicting criteria that need to be considered concurrently. In other words, the selection of WWT technology is indeed a multi- criteria or attributes decision problem. Method used in solving the problem must be flexible enough that allow several criteria to be taken into account simultaneously in a complex situation. A method must be designed to help decision-makers express their different options, which reflect the opinions of the actor involved [6]. In other words, a multi-criteria decision making approach is used where all criteria and possible alternatives are considered for dealing with complexity in selecting WWT technology.

The applications of various multi-criteria decision making (MCDM) techniques in solving WWT technologies have been widely discussed in many literature. Bottero et al. [2] used AHP and ANP on different wastewater treatment system. Multi-criteria analyses were used to make comparative assessments of alternatives projects or heterogeneous measures and allow several criteria to be taken into account simultaneously in a complex situation. Norese [7] used ELECTRE III as a support for participatory decision-making on the localization of wastewater treatment. Locating an incinerator and a facility to store ashes and other wastes is a long and complex process in Italy. The district of Turin faced this situation by selecting a participative approach to the problem and by using multi-criteria analysis as a support for a specific phase of the decision process. A group of 45 decision-makers (local authorities and representatives from the different communities that were involved) worked together with a facilitator group for 16 months to identify the criteria judged relevant to analyze the consequences of the location of the plant. Two multi-criteria models, one for the incinerator and the other one for the waste disposal plant, were elaborated and an ELECTRE method was used to compare sites and rank them with the aim of selecting the best sites to activate. Kalbar et al. [8] has conducted a research on selection of an appropriate wastewater treatment technology which is a scenario-based multiple-attribute decision-making approach. The four most commonly used wastewater treatment of municipal wastewater in India are ranked for various scenarios. Six scenarios were developed that capture the regional and local societal priorities of urban, suburban and rural areas and translate them into the mathematical algorithm of the TOPSIS methodology. Seven criteria with twelve indicators were formulated to evaluate the alternatives. Bottero et al., [2] and Beltran et al. [9] also applied multi-criteria decision analysis to jar-test results for chemical selection in the physical-chemical treatment of textile wastewater. In their result, the use of multi-criteria decision analysis was proposed to help on the selection of the coagulant and its concentration in the physical-chemical wastewater treatment, since textile wastewater contain hazardous substances. The AHP and PROMETHEE were used to analyse the decision problem.

There are substantial numbers of MCDM techniques that have been applied in WWT. However, very little information about the applications of weighted linear combination of matrices based on multi criteria decision analysis with fuzzy linguistic evaluations. One of the techniques purposely used linear combination of matrices to compute a weight of alternative is simple fuzzy simple additive weighting (FSAW). The FSAW is a MCDM method that combines the theory of fuzzy set [10] and simple additive weight (SAW) method [11]. The method uses trapezoidal fuzzy numbers to represent any imprecision in linguistic judgments over criteria and alternatives. Its calculations heavily involve trapezoidal fuzzy numbers where the laws of fuzzy arithmetic [12] are upheld. The FSAW has been successfully applied in diverse applications. Deni et al., [13], for example used FSAW method for selection of a high achieving student at faculty level. The linguistic data were obtained from the Faculty of Engineering, at a university in India. Kumar et al., [14] implemented FSAW in the selection of an appropriate maintenance strategy for material handling equipment in Punj Lyord plant Gwalior (India). Lin et al., [15] applied FSAW in their study with the objective to determine health examination institution location selection in Taipei Metropolitan. Abdullah and Jamal [16] modified fuzzy simple additive weight (FSAW) decision making model to describe the applications of a fuzzy decision making method in ranking indicators of Health-Related Quality of Life among kidney patients in a Malaysian government funded hospital. Kabassi [17] presented FSAW and applied it for evaluating personalized software. Rajaie et al., [18] proposed a simple multi-criteria system to assist decision makers in the decision process of ranking contractors. It seems that the method was given a little attention in solving WWT technology selections. Therefore, the aim of this paper is to develop a decision in selecting the WWT technology using FSAW. The rest of this paper is organized as follows. Section 2 presents some basic notations and definitions that are needed in this research. Section 3 presents the mathematical model of FSAW. In Section 4, implementation of FSAW to a case of WWT technology selection are presented. A conclusion is made in Section 5.

II. PRELIMINARIES

To develop decision with FSAW, some definitions and properties that related to FST are needed.

Definition 1 [19];[12].

Let a fuzzy set $\tilde{A}=(a,b,c,d)$ where $\tilde{A}\in\Re$, and $a<b<c<d$ is called as trapezoidal fuzzy number if the membership function satisfies;

$$\mu_{\tilde{A}}(x)=\begin{cases}\dfrac{x-a}{b-a}, a\le x\le b\\ 1, b\le x\le c\\ \dfrac{x-d}{c-d}, c\le x\le d\\ 0, otherwise\end{cases} \tag{1}$$

The membership of this function can be depicted in Fig 1.

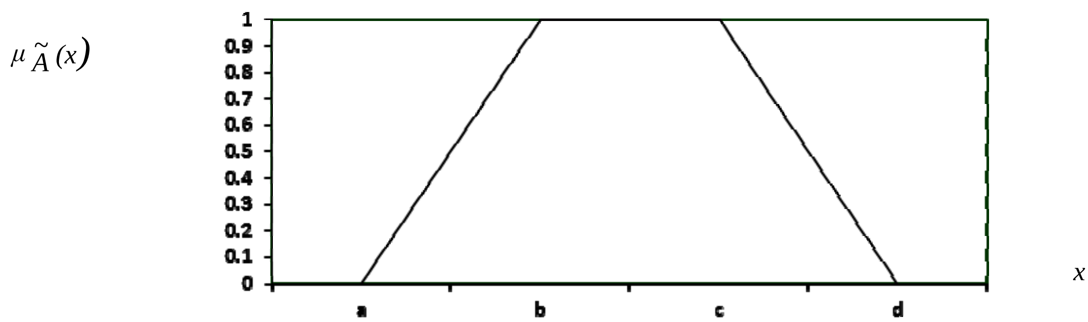

Fig. 1. Trapezoidal fuzzy numbers (a,b,c,d)

Fig 1 visualizes the trapezoidal fuzzy number that is symbolized by (a,b,c,d) .Trapezoidal fuzzy numbers are highly acceptable due to its simplicity in term of arithmetic and can be interpret intuitively. Trapezoidal fuzzy numbers have several properties regarding the fuzzy arithmetic operations.

Property 1 [12];[20];[21];[22].

Let $\tilde{A}=(a,b,c,d)$ and $\tilde{B}=(e,f,g,h)$ be two trapezoidal fuzzy numbers. Then, they can be expressed as;

$$\tilde{A}\oplus\tilde{B}=(a+e,b+f,c+g,d+h) \text{ where } a\ge 0,e\ge 0 \tag{2}$$

$$\tilde{A}\otimes\tilde{B}=(ae,bf,cg,dh) \text{ where } a\ge 0,e\ge 0 \tag{3}$$

$$k\otimes\tilde{A}=(ka,kb,kc,kd) \text{ where } a\ge 0,k\ge 0 \text{ and } k\in\Re \tag{4}$$

$$\tilde{A}/\tilde{B}=\left(\frac{a}{h},\frac{b}{g},\frac{c}{f},\frac{d}{e}\right) \text{ where } a\ge 0,e\ge 0 \tag{5}$$

Property 2: If $k \in \Re$ and $\tilde{A} = (a,b,c,d)$, then the division operation of k and $\tilde{A}$ will be expressed as;

$$k / \tilde{A} = \left(\frac{k}{d}, \frac{k}{c}, \frac{k}{b}, \frac{k}{a}\right) \text{ where } a \geq 0, k \geq 0 \text{ and } k \in \Re \tag{6}$$

$$\tilde{A} / k = \left(\frac{a}{k}, \frac{b}{k}, \frac{c}{k}, \frac{d}{k}\right) = \frac{1}{k}\tilde{A} \text{ where } a \geq 0, k \geq 0 \text{ and } k \in \Re \tag{7}$$

Property 3: If $k \in \Re$, $\tilde{A} = (a,b,c,d)$, and $\tilde{B} = (e, f, g, h)$, then the commutative operation of them will be expressed as;

$$\tilde{A} \oplus \tilde{B} = \tilde{B} \oplus \tilde{A} \tag{8}$$

$$\tilde{A} \oplus k = k \oplus \tilde{A} \tag{9}$$

$$\tilde{A} \otimes \tilde{B} = \tilde{B} \otimes \tilde{A} \tag{10}$$

$$\tilde{A} \otimes k = k \otimes \tilde{A} \text{ where } a \geq 0, k \geq 0, e \geq 0 . \tag{11}$$

Besides, the insertion of trapezoidal fuzzy numbers in FSAW, there is property of signed distance that directly related with algorithm in FSAW.

Property 4 [23].

The signed distance of trapezoidal fuzzy number $\tilde{A} = (a,b,c,d)$ is defined as

$$d(\tilde{A}) = \frac{1}{4}(a+b+c+d) \tag{12}$$

The signed distance method is used to defuzzify a trapezoidal fuzzy number.

III.FSAW AND ITS ALGORITHM

Generally, the algorithm of this method involves three major states; rating state, aggregation state, and selection state. Details of the three states are as follows.

3.1 Rating state

In rating state, a tool of collecting linguistic data in form of questionnaire is prepared for a group of decision-makers. They will ask to rate their opinions on alternatives with respect to each criteria. Their opinions or verbal assessments are translated into trapezoidal fuzzy numbers. The structured questionnaire must consist of the identified criteria and its corresponding alternatives.

3.2 Aggregation state

In aggregation state there are several steps that need to be implemented. To aggregate, the following simplified list of steps must be executed [24]. Firstly, the aggregated fuzzy weights (AFW) of each criterion are constructed based on linguistic weighting variable introduced by decision-makers. The aggregated fuzzy ratings (AFR) of alternatives with respect to each subjective criterion are computed based on linguistic rating variable. A fuzzy rating matrix is constructed from the computed fuzzy ratings in the third step. Finally, the total fuzzy scores of each alternative are computed by multiplying the calculated fuzzy rating matrix with their corresponding weight vectors. In FSAW, the fuzzy assessment decided by the decision-makers can be aggregated into several methods which are mean, median, max, min, mixed operators and many more [25]. However, mean is commonly used in aggregation method even though the importance of each decision-maker may affect the final result in term of unbalance in practice.

3.3 Selection state

The selection state consist of defuzzification and ranking phase. In defuzzification phase, the fuzzy weights of each criterion and the total fuzzy scores for each alternative are defuzzified. Then, the defuzzified alternatives are then ranked by the crisp value of total scores [24].

3.4 Algorithm

The algorithm of this method is described as follows [24].

Step 1: Decision-makers, criteria, and suitable alternatives must be identified. .

Step 2: Determine the degree of importance of decision-makers. The decision-makers are presumed to be homogenous group ($I_1 = I_2 = \cdots = I_k = \frac{1}{k}$)if the degree of importance is equal. Otherwise the decision makers are heterogeneous.

$$I_t = \frac{d(\tilde{w}_t)}{\sum_{t=1}^{k} d(\tilde{w}_t)} \tag{13}$$

where

$\sum_{t=1}^{k} I_t = 1$

$\tilde{w}_t$ =fuzzy weight

$d(\tilde{w}_t)$ =defuzzified value of fuzzy weight by using signed distance

I_t is the degree of importance of decision-makers where is I_t defined on [0,1], t is defined on [$1,k$] and k is the decision makers.

Step 3: Set linguistic weighting variables so that decision makers can evaluate the importance of criteria. Fuzzy linguistic variables are shown in Table 2.

TABLE 2
Fuzzy numbers for linguistic weighting variables

Linguistic Variable		Fuzzy Numbers					
Very Not Important	VNI	(	0	0	0	3	)
Not Important	NI	(	0	3	3	5	)
Medium	M	(	2	5	5	8	)
Important	I	(	5	7	7	10	)
Very Important	VI	(	7	10	10	10	)

Equation (14) is used to compute AFW;

$$\tilde{W}_j = (I_1 \times \tilde{W}_{j1}) + (I_2 \times \tilde{W}_{j2}) + \ldots + (I_k \times \tilde{W}_{jk}) \quad (14)$$

$\tilde{W}_j$ =aggregated fuzzy criteria weight = (a_j, b_j, c_j, d_j)

$a_j = \sum_{t=1}^{k} I_t a_{jt}$, $b_j = \sum_{t=1}^{k} I_t b_{jt}$, $c_j = \sum_{t=1}^{k} I_t c_{jt}$, $d_j = \sum_{t=1}^{k} I_t d_{jt}$

$\tilde{W}_{jt} = (a_{jt}, b_{jt}, c_{jt}, d_{jt})$ = Linguistic weight to subjective and objective criteria by k decision maker where $j = 1,2,\ldots,n$

Step 4: Compute normalize weight and construct weight vector to defuzzify the fuzzy weights of each criteria. Adopt the signed distance in the calculation.

$$d(\tilde{W}_j) = \frac{1}{4}(a_j + b_j + c_j + d_j) \quad (15)$$

$d(\tilde{W}_j)$ = defuzzification of $\tilde{W}_j$ where $j = 1,2,\ldots,n$

$W_j = \dfrac{d(\tilde{w}_t)}{\sum_{t=1}^{k} d(\tilde{w}_t)}$ =crisp value of normalize weight for criteria C_j

Step 5: Use the linguistic rating variables in Table 3 so that DMs can evaluate fuzzy rating of alternatives with respect to each subjective criterion.

TABLE 3
Fuzzy numbers for linguistic rating variables

Linguistic Variables		Fuzzy Numbers					
Very Not Important	VNI	(	0	0	0	20	)
Between Very Not Important and Not Important	VNI-NI	(	0	0	20	40	)
Not Important	NI	(	0	20	20	40	)
Between Not Important and Fairly Important	NI-FI	(	0	20	50	70	)
Fairly Important	FI	(	30	50	50	70	)
Between Fairly Important and Important	FI-I	(	30	50	80	100	)
Important	I	(	60	80	80	100	)
Between Important and Very Important	I-VI	(	60	80	100	100	)
Very Important	VI	(	80	100	100	100	)

Then, compute aggregate fuzzy rating (AFR) for each alternative-criterion combination using Eq (16),

$$\tilde{X}_{ij} = (I_1 \times \tilde{X}_{ij1}) + (I_2 \times \tilde{X}_{ij2}) + \ldots + (I_k \times \tilde{X}_{jik}) \quad (16)$$

where $\tilde{X}_{ij} = (O_{ij}, p_{ij}, q_{ij}, s_{ij})$ =aggregated fuzzy rating of alternatives for subjective criteria

$j = 1,2,..., h$ and $i = 1,2,..., m$

$$O_{ij} = \sum_{t=1}^{k} I_t O_{ijt}\ ;\ p_{ij} = \sum_{t=1}^{k} I_t p_{ijt}\ ;\ q_{ij} = \sum_{t=1}^{k} I_t q_{ijt}\ ;\ s_{ij} = \sum_{t=1}^{k} I_t s_{ijt}$$

Step 6: From fuzzy ratings, construct fuzzy rating matrix $\tilde{M}$

$$\tilde{M} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & & \cdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \quad (17)$$

Step 7: Multiply fuzzy ratings by their weight vectors to get total fuzzy score for each alternative.

$$\tilde{F} = \tilde{M} \otimes W^T = \begin{bmatrix} \tilde{f}_1 \\ \tilde{f}_2 \\ \vdots \\ \tilde{f}_m \end{bmatrix} \quad (18)$$

$\tilde{M}$ = fuzzy rating matrix

W^T = corresponding weight vector

$\tilde{f}_i = (r_i, s_i, t_i, u_i)$ where $i = 1,2,..., m$

Step 8: By defuzzification method, find the crisp value for each total score. Next, select alternative with the maximum total score. Here, the best alternative is determined by the rank total fuzzy score by signed distance. Then, rank the alternatives from the crisp value of total score for each alternative.

$$d(\tilde{f}_j) = \frac{1}{4}(r_i + s_i + t_i + u_i) \quad (19)$$

where $d(\tilde{f}_j)$ = defuzzified value (crisp value) of total fuzzy score of alternatives and

$i = 1,2,..., m$.

These eight steps computation procedure are implemented to a case of selecting suitable WWT technology.

IV. A CASE OF WWT TECHNOLOGY SELECTION

This section proposes a decision for selecting the suitable WWT from three different WWT system technologies using FSAW. Three decision makers were sought to provide linguistic evaluation data based on the FSAW framework. Three experts comprise two academicians, (D1), (D2) from Department of Environmental Engineering, Faculty of Science and Technology at a public university and an engineer (D3) from Department of Environment at a government ministry in Malaysia. These experts need to evaluate weights of criteria and also criteria with respect to the three alternatives using the linguistic variables. The criteria are economic aspect (C1), technological aspect (C2) and environment aspect (C3). The alternatives of WWT technologies are anaerobic digestion (A1), phytoremediation (A2) and compositing (A3). The linguistic variables in Table 1 and Table 2 are use as evaluation scales. Details of the implementation are given in step-wise procedure as follows.

Step 1: Identify decision-makers, criteria and alternatives.

Decision-makers: D1, D2 and D3

Criteria: Economic Aspect (C1), Technological Aspect (C2) and Environment Aspect (C3)

Alternatives: Anaerobic Digestion (A1), Phytoremediation (A2) and Composting (A3).

Step 2: Determine degree of importance of the decision makers.
The three decision-makers are presumed to be equally important. So, from Equation (13), the degree of importance of decision makers is homogenous.
Step 3: Determine weight of importance for the criteria
Based on linguistic weighting variables in Table 2, weights of importance for criteria are determined. Decisions against the three criteria are given in Table 4.

TABLE 4
Importance weights of criteria

Criteria	**Decision-makers**		
	D1	D2	D3
Economic Aspect, C1	V1	VI	VI
Technological Aspect, C2	I	I	VI
Environment Aspect, C3	I	VI	I

Using Equation (14), the average fuzzy weighted (AFW) for each criterion is computed. Table 5 presents the fuzzy weights of the criteria.

TABLE 5
Fuzzy weights of the criteria and AFW

Criteria	**Decision makers**												**AFW**			
	D1				D2				D3							
C1	7	10	10	10	7	10	10	10	7	10	10	10	7	10	10	10
C2	5	7	7	10	5	7	7	10	7	10	10	10	5.67	8	8	10
C3	5	7	7	10	7	10	10	10	5	7	7	10	5.67	8	8	10

Step 4: Normalized the weights.

The weight vector *W* is constructed to defuzzify the fuzzy weight of each criterion using Eq (15). The defuzzied values and normalized weights are given in Table 6.

TABLE 6
Defuzzified values of AFW and normalized weights of criteria

Method	**Criteria**			**Total**
	C1	C2	C3	
Defuzzified values	9.25	7.91667	7.91667	25.0833
Normalized weight	0.36877	0.31561	0.31561	1.0000

So, weight vector is obtained as $W = [0.36877, 0.31561, 0.31561]$

Step 5: The linguistic variables in Table 3 are used by decision makers to evaluate fuzzy rating of alternatives with respect to each subjective criterion. Evaluation of all decision makers against alternatives with respect to C1 and AFR are given in Table 7.

TABLE 7
Evaluation of DMs for criterion with respect to alternatives

C1	**D1**				**D2**				**D3**				**AFR**			
A1	60	80	80	100	30	50	80	100	60	80	80	100	50	70	80	100
A2	30	50	50	70	30	50	80	100	30	50	80	100	30	50	70	90
A3	80	100	100	100	0	20	50	70	30	50	50	70	36.67	56.67	66.67	80

The similar evaluations and AFR are also computed for rating C2 and C3 with respect to alternatives.

Step 6: From the calculated AFR, the fuzzy ratings matrix is constructed. It is shown in Table 8.

TABLE 8
Fuzzy rating matrix

Alternatives	**Criteria**											
	C1				C2				C3			
A1	50	70	80	100	46.67	66.67	86.67	100	66.67	86.67	100	100
A2	30	50	70	90	40	60	76.67	90	66.67	86.67	93.33	100
A3	36.67	56.67	66.67	80	46.67	66.67	76.67	90	66.67	86.67	93.33	100

Step 7: Total fuzzy scores for each alternative are computed using Eq (18). It is shown in Table 9.

TABLE 9
Total scores of alternatives

Alternatives		**Total scores**			
A1	Fuzzy numbers	72.22	74.44	88.89	100
A2	Fuzzy numbers	45.56	65.56	80	93.33
A3	Fuzzy numbers	50	70	78.89	90

Step 8: The defuzzification equation (Eq (19)) is used to obtain the crisp values of total scores. The total crisp scores of each alternative are presented in Table 10.

TABLE 10
Crisp value of total score

Alternatives		**Total scores**
A1	Deffuzified values	83.89
A2	Deffuzified values	71.11
A3	Deffuzified values	72.22

The suitable WWT system technologies are ranked according to the total scores. Alternative A1 scores the highest followed by A3 and A2. Therefore, the best technology for WWT is anaerobic digestion followed by compositing and phytoremediation.

V. CONCLUSIONS

Multi-criteria decision making is used to make evaluation of alternatives and allow several criteria to be taken into account simultaneously in a complex decision situation. The paper have shown the application of fuzzy simple additive weighting to a real decision problem concerning the selection of the most sustainable wastewater treatment technology, namely Anaerobic digestion, Phytoremediation and Composting. The FSAW has been considered for prioritizing the different technologies. The method accounts all criteria and alternatives of the decision process. The identified criteria are environmental aspects, technological factors and economic costs, and the three technologies as alternatives. The concept of fuzzy simple additive weighting was linked to the fuzzy set theory, factor rating system, and simple additive weighting to improve its ability to solve the selection problem of WWT technology with imprecise criteria. The method allows tangible and intangible elements to be incorporated simultaneously in the evaluation. The weights obtained from the selection process indicate that anaerobic digestion is the most sustainable WWT technology. This research has thrown up several questions in need of further investigations. The list of technologies, reliability of experts and the validity of the FSAW are among several key questions that need to be considered in future research.

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AUTHOR PROFILE

Lazim Abdullah is Professor at the School of Informatics and Applied Mathematics, University of Malaysia Terengganu. He holds a B.Sc (Hons) in Mathematics from the University of Malaya, Kuala Lumpur in June 1984 and the M.Ed in Mathematics Education from University Sains Malaysia, Penang in 1999. He received his Ph.D. from the University of Malaysia Terengganu, (Information Technology Development) in 2004. His research focuses on the mathematical theory of fuzzy sets and its applications in social ecology, environmental sciences, health sciences, and manufacturing engineering. He is interested in the measurement of social indicators, indices of health related quality of life and environmental index using computational intelligence and statistical approaches. His research findings have been published in over two hundred publications including refereed journals, conference proceedings, and chapters in book, and research books. Currently he is a member of editorial boards to several international journals related with computing and information technology. Besides, he is also a reviewer for number of local and international journals, member of scientific committees of several symposia and conferences at national and international levels. Dr Lazim is an associate member IEEE Computational Intelligence Society, a member of Malaysian Mathematical Society and a member of the International Society on Multiple Criteria Decision Making.