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A Conflicting Bifuzzy Evaluation Approach in Multi-Criteria Decision Making

[1]**Zamali Tarmudi***, [2]**Mohd Lazim Abdullah**, and [3]**Abu Osman Md Tap**

[1, 2]Department of Mathematics, Faculty of Science and Technology, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, MALAYSIA

[3]University of Taibah, P.O. Box 344, Medinah Munawwarah, Kingdom of Saudi Arabia
[1]E-Mail (Corresponding author): zamaliayg@hotmail.com;
[2]E-Mail: lazim_m@umt.edu.my; [3] E-Mail: amantap@yahoo.com

Abstract

The multi-criteria decision-making method has received significant attention by both researchers and decision makers due to its ability to derive effectively a compromise solution in the decision process. The focus of this paper is to propose a conflicting bifuzzy evaluation in the overall decision process using linguistic expressions. The approach is based on the new theory sets, the so- called 'conflicting bifuzzy sets' (CBFS) which are an extension of Atanassov intuitionistic fuzzy sets (IFS). A definition of the CBFS is discussed and the approach employs a multi-criteria decision making (MCDM) hybrid model which is developed using a fuzzy analytic hierarchy process and fuzzy ideal solution. Through this proposed approach, the decision maker needs to evaluate all the qualitative criteria using totally linguistic expressions through both positive and negative aspects such as 'very good', 'good', 'slightly poor' etc.. The direct assigned was employed to derive the importance weight of the criteria and the best compromise options among the potential alternatives was measured by performance index. A hypothetical example of municipal solid waste (MSW) disposal alternatives was given to verify the feasibility of the proposed approach. Based on the calculations, the approach is comprehensive in concept, very flexible, suitable for various decision situations and very promising result to derive the holistic evaluation, particularly in complex MCDM problems.

Keywords: Analytic hierarchy process (AHP), conflicting bifuzzy sets(CBFS), fuzzy ideal Solution (FIS), linguistic assessment, multi-criteria decision making (MCDM)

Mathematics subject classification: 03E72, 03Exx

1. INTRODUCTION

The requirement to get the best decision in any selection problem is a common, natural behaviour of a human being who is involved in a daily decision-making environment. It addresses the problem of choosing the optimal solution that has the highest degree of satisfaction from a set of alternatives (Wu and Chen, 2007). This phenomenon occurs because every entity, either as an individual or organisation, will face global competition from their competitors. Since the decision-making process has become more and more complex recently, the decision maker has a greater need for an effective evaluation approach to assist his/her decision process with ease and suited for various decision situations to express his/her judgement for certain evaluation events. By linguistic expressions, the experts can express directly their preference or opinion with respect to the qualitative criterion, while the cost-benefit criterion was utilised in the case of quantitative data. This is because, in many cases, experts are unable to give their preference degree directly using the exact values. They feel more comfortable with natural languages such as "very good", "good", slightly good", etc. (Herrera and Herrera-Viedma, 2000; Tsaur, et al. 2002; Xu, 2005), instead of numeric values like 1, 3, 5, etc..

Since a MCDM method offers a promising solution in various applications, a comprehensive evaluation approach is very critical in any decision process. Presently, most of the multi-criteria solutions made only consider the 'positive' aspects without considering even one of the opposite aspects (i.e. negative aspects). Although this approach seemed perfect so far, actually it has certain shortcomings that can be improved in the evaluation process. Therefore, this paper was initiated with the new idea, the so-called 'conflicting approach', based on the conflicting bifuzzy sets (CBFS) (Zamali, et al. 2008). With this proposed approach, all decision makers (DMs) must consider both positive and negative aspects simultaneously in the judgement process. Based on the literature,, it was found that no established research emphasises this approach, although it is very significant and related with the real problems encountered in the real world...

Thus, the aim of this paper is to utilise the linguistic assessment in the overall process of proposed MCDM model based on the conflicting evaluation concept. Since the nature of the criteria or attribute evaluated is subjective and has a lack of information, this approach is more precise, comfortable, user friendly and efficiently in daily decision-making procedures. In this paper, we focus our attention on developing a MCDM model using mean fuzzy numbers (Cheng, 1999) and triangular fuzzy numbers (TFNs) based on the conflicting approach. The rest of this paper is organised as follows. Section 2 discusses related literatures for MCDM using linguistic approaches, followed by section 3 which introduces the new proposed sets theory, the so-called 'conflicting bifuzzy sets', their families and links with others sets theory. Section 4 develops the proposed model combining both AHP and fuzzy ideal solution (FIS) with emphasis on both qualitative and quantitative information. The hypothetical example related to the municipal solid waste (MSW) disposal alternative is given in section 5 to demonstrate the applicability and practicality of our proposed approach. Lastly the conclusion is given in section 6.

2. RELEVANT LITERATURES

MCDM is the process of screening, priortising, ranking or selecting a set of alternatives under usual independent variables, incommensurate of conflicting criteria (Fenton and Wang, 2006; Belton and Steward, 2002). It also refers to the optimal solution in the judgemental process after a thorough screening of several available options among the alternative considerations. MCDM addresses the problem of selecting an optimum choice that has the highest degree of satisfaction from a set of alternatives that are characterised in terms of their attributes (Wu and Chen, 2007). In most cases, evaluation must be multi-faceted rather than single-faceted. In other words, it is common that several and conflicting criteria are considered simultaneously in the judgemental process (Asai, 1992). According to Beccali et al. (2003), MCDM methods in general can offer for at least three folds benefit; i) as a decision-makers aid for fixed 'general' objectives, ii) to use representative data and transparent assessment procedures, and iii) to assist the accomplishment of decisional process, focusing on increasing its efficiency.

In the literature, many variations on the theme MCDM are found, depending upon the theoretical basis used for the modeling. Generally, it can be classified into two brands; i) multiple objective decision-making (MODM), and ii) multiple attribute decision making (MADM), and both brands are categorised depending on the structure of the problem. This classification seems similar to the views of Zeleny (1982), which categorised both types of MCDM problems into two major theoretical approaches. The MODM usually has an infinite number of solutions, implicit and non predetermined, and the nature of the feasible region is continuous (Islam, 2003). The common methods in this category are goal programming, lexicographic method, step method (STEM), Geoffrin-Dyer-Feignberg method, Zionist-Wallenious method, etc. It arises in the planning of many complex systems, production, health, design, operation and control, local government administration, portfolio selection, operation and control of the firm, etc. The comprehensive application surveyed in various multi-objective mathematical programming can be found in Steur (1986) and White (1990). Meanwhile, the MADM problem may have few alternatives or many alternatives and can be classified based upon *non-compensatory* and *compensatory* models. In *non-compensatory* model, the trade-offs among attributes are not permitted and the evaluation of alternatives would be made separately for each attributes. The disjunctive constraint method, maximin method, conjunctive constraint method, lexicographic method, etc are example methods in this category. For *compensatory* model however, the changes in one attribute can be off-set by opposing changes in any other attributes, and this model can be further divided into three sub-categories; i) scoring model, ii) compromising model, and iii) concordance model. The famous method in scoring model including simple additive weighting (SAW) method, analytic hierarchy process (AHP), interactive simple additive weighting method, etc, while for compromising model, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Linear Multidimensional Analysis of Preference (LINMAP), etc. are the obvious method used in recent application. Finally, the methods such as permutation method, linear assignment method, and Elimination Et Choice by Translating Reality (ELECTRE) are the famous methods in the concordance model category. For interested readers, the details of the method taxonomy can be found in Hwang and Yoon (1981).

Carlsson and Fuller (1996) however classified MCDM into four major families; i) the utility theory approach pioneering work by Keeney and Raiffa, ii) the outranking method introduced by Roy, iiii) group decision and negotiation theory which is emphasis on the objectives among group members, and iv) the interactive multiple objective programming method introduced by Yu, Zeleny, Steuer, etc. Moreover, they also introduced the concept of interdependence in MCDM, and some researches have shown that fuzzy set theory could be successfully applied to resolve multiple criteria problems (Chin and Chin, 1998, Powell, 2000, Guleda et al. 2004, Hung et al. 2007, etc). Since fuzzy set theory has advanced recently in several applications, this entire category observed growth in line with the role of fuzzy implementation in MCDM research. For example, the α-cuts, comparison function, fuzzy mean and spread, degree of optimality are among the number of ways to find the ranking in fuzzy environment.

As MCDM problems become increasing complicated and complex, the requirement to develop a precision model is vital and increasing significant attention is now given by researchers worldwide. Many researches' have proposed a variety of fuzzy methods with different approaches to deal with the uncertainty occurring during the developing model and evaluation process. Fenton and Wang (2006), present the risk and confidence analysis using linguistic variables and triangular fuzzy numbers to deal with the uncertainty aspect in the decision process. They modelled the DMs risk and confidence attitudes to define a more complete MCDM solution. Based on the computation example shown, the method is useful for tackling the imprecision and subjectivity in complex, ill-defined and human-oriented decision problems. Several models have been developed in recent decades to support decision making in various applications. Three models were identified based on high frequency of use, MCDM and multi-objective programming (MOP), as well as a Life Cycle Assessment (LCA). LCA is usually used to evaluate the environmental impact of the alternatives for MSW management (Powell, et al. 1996; Barton, et al. 1996; Finnveden, 1999; Powell, 2000; Eriksson, et al. 2002) while

MOP is for choosing the location sites and management strategies (Chang and Wang, 1996; Chang and Wei, 1996). Alternatively MCDM is used for choosing the best alternative by considering multiple criteria. For example, the AHP method is employed for solving environmental problems with multiple-criteria (Haastrup, et al. 1998; Trans, et al. 2002), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method (Hwang and Yoon, 1981), and outranking method (Geldeman, et al. 2000; Roy, 1990). Among these three methods, MCDM is the most commonly-used method, as it facilitates selecting the best choice among several alternatives by assessing numerous criteria (Hung, et al. 2007). For example, studies on urban quality assessment (Guleda, et al. 2004), selection of senior teachers (Chin and Chin, 1998), evaluating airline service quality (Chung and Yu, 2003), optimising the spending of fuel storage (Moon and Kang, 2001) and reservoir water index (Yi and Shang, 2005), etc.

In short, there are many MCDM methods which have been used to deal with a variety of applications, and the main approaches can be classified based on the type of decision model used (Chiou et al. 2005). However, in general, the four most common and often MCDM method used are as follows:

- Goal Programming (GP) – the model requires a priori specification of multiple goals or aspiration levels.
- Multi-Attribute Utility Theory (MAUT) – It deals with the problems under uncertainty and risk as well as trade-off values among attributes.
- Elimination Et. Choice by Translating (ELECTRE) – the model arranges a set of preference rankings which best satisfies a given concordance measure.
- Analytic Hierarchy Process (AHP) – the pairwise comparison technique to compare criteria and alternative to derive the weighted values.

In spite of significant development that have taken place in both MCDM theoretical and applications, existing research very rare to explore the conflicting approaches in fuzzy environment as a decision support system to assist decision makers in MCDM problems. Thus, in this research, the model was developed based on the conflicting bifuzzy approach encompassing AHP (Saaty, 1980) and FIS (Chen, 2000) to suit with the proposed method.

3. IDEA OF CONFLICTING BIFUZZY SETS THEORY (Zamali et al. 2008)

For the purpose of reference, in this section some of the definitions are reviewed which related to the idea that we have propose, namely the ‘conflicting bifuzzy set’ theory.

Since Zadeh (1965) proposed his idea of fuzzy sets theory, the application of this concept is extremely great and advanced in various areas. However, fuzzy sets only give a membership degree to each element of the universe, and the non-membership degree is always equivalent to the complimentary basis (Deschrijver and Kerre, 2007).

Definition 1 A fuzzy set A in a universe of discourse X is characterised by a membership function $\mu_A(x)$ that takes the values in the interval of [0,1]. It can be denoted as follows:

$A = \{(\mu_A(x)/x);\ x \in X\}$

Atanassov (1986) extended Zadeh’ idea by using the concepts of dual membership degrees in each of the sets discourse by giving both a degree of membership and a degree of non-membership which are more-or-less independent from one other with the sum of these two grades being not greater than 1 (Deschrijver and Kerre, 2007).

Definition 2 Let a set *A* be fixed. An intuitionistic fuzzy set or IFS *A* of *U* is an object having the form
$A = \{\langle x, \mu_A(x), \gamma_A(x)\rangle \mid x \in U\}$
where the function $\mu_A(x) : U \to [0, 1]$ and $\gamma_A(x) : U \to [0, 1]$ define, respectively, the degree of membership and degree of non-membership of the element $x \in U$ to the set *A*, which is a subset of *U*, and every $x \in U$, $0 \le \mu_A(x) + \gamma_A(x) \le 1$.
Through this new idea, many applications have been utilised by IFS concepts in various fields. However, IFS seems like it has the potential to be extended by ignoring or releasing the $0 \le \mu_A(x) + \gamma_A(x) \le 1$ condition. Therefore, a new concept of evaluation approach is proposed by utilising both the positive and negative aspects simultaneously. The CBFS defined as follows:

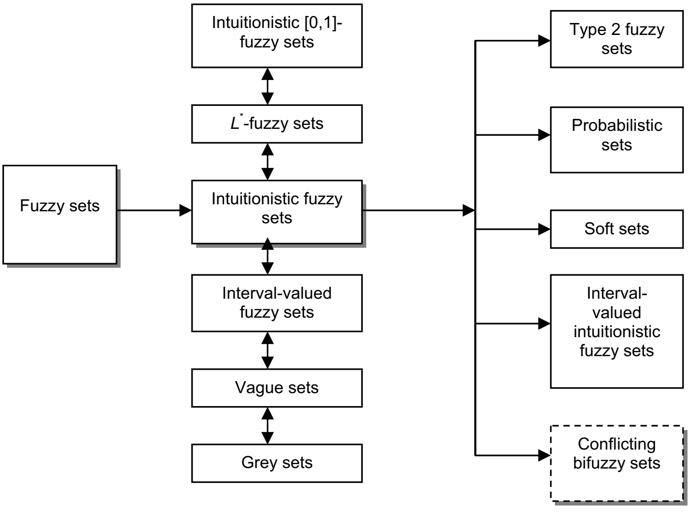
Definition 3 Let a set *X* be fixed. A conflicting bifuzzy set *Z* of *X* is an object having the following form:

$$Z = \{<x, \mu_z(x), \upsilon_z(x)>/x \in X\},$$

where the functions $\mu_z : X \to [0, 1]$ represent the degree of positive *x* with respect to *Z* and $x \in X \to \mu_z(x) \in [0, 1]$, and the functions $\upsilon_z : X \to [0, 1]$ represent the degree of negative *x* with respect to *Z* and $x \in X \to \upsilon_z(x) \in [0, 1]$.

The operations of two conflicting bifuzzy sets *A* and *B* in *X* is similar with the *IFS*. The only difference is that the sum of these two grade degrees can exceed more than 1 (in a logical range based on the experts' experiences). Based on the above definition, it is clear that the CBFS theory (Abu Osman, 2006) is an extension of intuitionistic fuzzy sets which was proposed by Atanassov. The relationship between Zadeh fuzzy sets, Atanassov fuzzy sets and our proposed fuzzy sets are shown as Figure 1.

Figure 1: The links between intuitionistic fuzzy sets and others set theories (Deschrijver and Kerre, 2007)



Note: The 'single arrow' (A → B) denotes that B is an extension of A, and a 'double arrows' (A ↔ B) means that they are equivalent, between two theories, respectively.

4. MODEL DEVELOPMENT AND FORMULATION

Since the nature of the MSW disposal selection problem involves multiple factors and various considerations from different stakeholders (e.g., government, experts, NGOs, etc.), the model must comply with the basic of integrated group decision makers. In this section, we briefly describe the general approach of the MCDM hybrid model combining both fuzzy AHP (Saaty, 1980) and fuzzy ideal solution (Chen, 2000).

Figure 2: The four levels of hierarchy structure

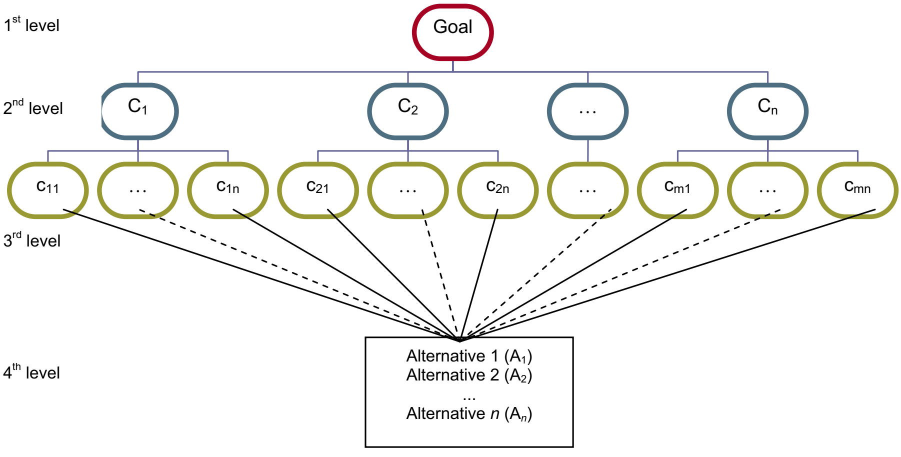


Table 1: The importance weight of each criterion

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

Table 2: Linguistic variables for the ratings

Linguistic variables	Symbol	TFN
Very poor	VP	(0,0,1)
Poor	P	(0,1,3)
Medium poor	MP	(1,3,5)
Fair	F	(3,5,7)
Medium good	MG	(5,7,9)
Good	G	(7,9,10)
Very good	VG	(9,10,10)

4.1 Establish the hierarchy structure

To formulate the problems more easily, the actual problems are transformed into a hierarchy structure (Figure 2). As we can see, the structure has 4 levels of hierarchy which is contains the objective or goal of the study at the first level, followed by some related criterion to support the problems objective in the second level. The third level encompasses the sub-criteria for each criterion from level two, and the alternative lies in the last level (fourth level).

4.2 Calculate the performance score of the criteria and sub-criteria

The direct assign by linguistic variables is used as shown in Table 1 and 2 above, for stakeholders evaluate the importance of the criteria and sub-criteria. The main reason to use this direct assign is due to it's being very convenient from multi-field stakeholders' background and more user friendly compared with the conventional methods (i.e., exact figures etc.)

To deal with the qualitative and quantitative original data, two methods were utilised (Ching, et al. 1999) as follows:

- Qualitative data - the fuzzy linguistic variables used the TFNs derive its corresponding value as in Table 2, and as shown in Figure 3.
- Quantitative data – consult with the stakeholders to estimate the reasonable input of data, based on their expertise and experiences.

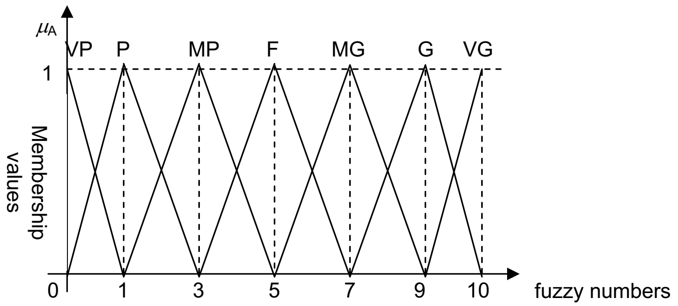
4.3 Group aggregation of the stakeholders

In many cases, the relative importance of the stakeholder is widely different. Thus, the relative important weight of each stakeholders was considered, and to assign the different important weight, firstly, we identify the most important stakeholder(s), s^k among the group is assigned '1' *i.e.*, $w_k = 1$. Then we compare s^k with the ith stakeholders s^i ($i = 1, 2, \ldots, n$) . Hence, we have $\max\{s^1, s^2, \ldots, s^n\} = 1$ and $\min\{s^1, s^2, \ldots, s^n\} > 0$. Lastly, we define the relative of important weight for each stakeholder as follows (Hsu and Chen, 1996; Zhang and Lu, 2003):

$$w_k = \frac{s^k}{\sum_{i=1}^{n} s^i}, \quad i = 1, 2, ..., n. \qquad -(1)$$

On the other hand, if the importance of each stakeholders' is equal then $w_1 = w_2 = \ldots = w_n = \frac{1}{n}$.

Figure 3: Membership functions of linguistic values for criteria ratings



4.4 Construct the fuzzy decision matrix

Generally, the fuzzy multi-criteria decision matrix concisely can be expressed in the following format

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ \ldots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \ldots & C_n \end{array} \\ \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \ldots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \ldots & \tilde{x}_{2n} \\ \ldots & .. & \ldots & \ldots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \ldots & \tilde{x}_{mn} \end{bmatrix} \end{array}, \quad \text{and} \quad \tilde{W} = \left[\tilde{w}_1, \ \tilde{w}_2, \ \ldots, \ \tilde{w}_n \right] \qquad \text{-(2)}$$

where A_1, A_2, …, A_m are possible alternatives, C_1, C_2, …, C_n are criteria with which performance of alternatives are measured using linguistic variables. These linguistic variables can be described by triangular fuzzy number, $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ and $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$.

4.5 Normalisation

To avoid complexity, the linear scale transformation is used to deal with quantitative criteria on different scales into a comparable scale. Thus, the TFN was normalised, $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ (i = 1, 2, …, n; j =1, 2, …, m), in the decision matrix as the performance matrix denoted by $\tilde{R}$.

$$\tilde{R} = \left(\tilde{r}_{ij} \right)_{m \times n} \qquad \text{-(3)}$$

where
$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{M}, \frac{b_{ij}}{M}, \frac{c_{ij}}{M} \right); \quad i = 1, 2, \ldots, n; \ j \in B \qquad \text{-(4)}$$

$$\tilde{r}_{ij} = \left(\frac{N - c_{ij}}{N}, \frac{N - b_{ij}}{N}, \frac{N - a_{ij}}{N} \right); \quad i = 1, 2, \ldots, n; \ j \in C \qquad \text{-(5)}$$

$$M = \max_j c_{ij}, \quad j \in B \text{ (benefit criteria), and} \qquad \text{-(6)}$$

$$N = \max_i c_{ij}, \quad j \in C \text{ (cost criteria),} \qquad \text{-(7)}$$

B is a set of benefit criteria, where the higher the value of $\tilde{r}_{ij}$ the better it is for DM, and C is a set of cost criteria, where the lower the value of $\tilde{r}_{ij}$ the better it is for the DM., and this TFN normalisation method is to preserve the property in ranges of [0,1].

4.6 Calculate the FPIS and FNIS

Considering the different importance of each criterion, the weight performance matrix was constructed by multiplying the weight vector to the decision matrix as:

$$\tilde{V} = \left[\tilde{v}_{ij} \right]_{m \times n}, \quad i = 1, 2, \ldots, m, \ j = 1, 2, \ldots, n \qquad \text{-(8)}$$

where $\tilde{v}_{ij} = \tilde{r}_{ij} (\cdot) \tilde{w}_j$

Then, the fuzzy positive-ideal solution (FPIS, A^*) and fuzzy negative-ideal solution (FNIS, A^-) were defined as

$$A^* = \{v_1^*, \ldots, v_m^*\} = \{(\max_j c_{ij} / j \in B), (\min_j a_{ij} / j \in C)\}, \text{ and} \qquad \text{-(9)}$$

$$A^- = \{v_1^-, \ldots, v_m^-\} = \{(\min_j a_{ij} / j \in B), (\max_j c_{ij} / j \in C)\} \qquad \text{-(10)}$$

where, $\tilde{v}_j^* = (1, 1, 1)$ and $\tilde{v}_j^- = (0, 0, 0)$, j = 1, 2, …, n.

The vertex method is used to calculate the alternatives' performance index with reference to ideal solution. Let $\tilde{a} = (a_1, a_2, a_3)$ and $\tilde{b} = (b_1, b_2, b_3)$ be two triangular fuzzy numbers, then the vertex method is defined to calculate the distance between $\tilde{a}$ and $\tilde{b}$ as (Chen, 2000):

$$d(\tilde{a},\tilde{b}) = \sqrt{\frac{1}{3}\left[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2\right]} \qquad \text{-(11)}$$

The shortest distance from the positive ideal solution and the longest distance from the negative ideal solution is the most preferred alternative. Thus, the distance between each alternative and the FPIS and FNIS is calculated as:

$$d_1^* = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^*\right) \qquad \text{-(12)}$$

$$d_1^- = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^-\right) \qquad \text{-(13)}$$

where i =1, 2, …, m and j = 1, 2, …, n, and d (· , ·) is the distance measurement between two fuzzy numbers.

4.7 Calculate the performance index

A performance index (PI) is defined to determine the ranking order of all alternatives once the d_i^* and d_i^- of each alternative A_i (i = 1, 2, … , m) has been calculated. Hence, the PI for each alternative as (Fenton and Wang, 2006):

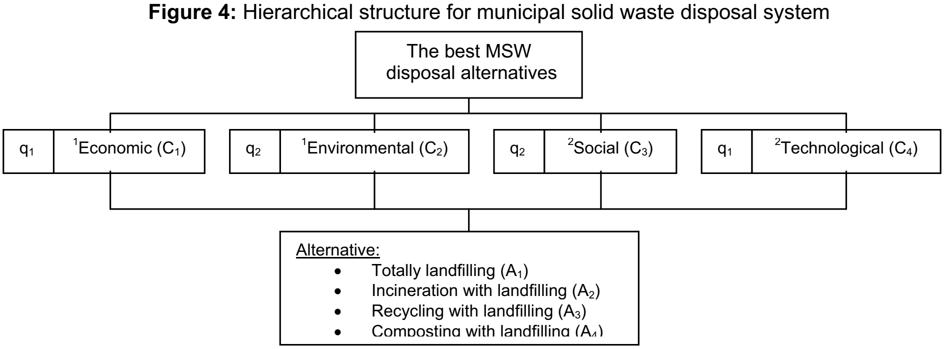
$$\mathrm{PI}_i = \frac{1}{2n}\left[d_i^- + n - d_i^*\right] \qquad \text{-(14)}$$

where i =1, 2, …, m and n is the number of criteria. The closer PI_i obtained to 1 the better the alternative's performance.

4.8 Determine the ranking order

According to the closeness of performance index from sub-section 4.7, the ranking order of the n alternatives, A_1, A_2, …, A_n can be determined. For example, if the ranking of n alternatives as, $A_3 \rangle A_{n-4} \rangle \ldots \rangle A_{n-9}$, then we can conclude that A_3 is the most preferred option followed by A_{n-4} and so on, and A_{n-9} is the last preferred option, where the symbol '$\rangle$' means 'is superior or preferred to'.

Figure 4: Hierarchical structure for municipal solid waste disposal system



Note: $q_1 \approx$ quantitative data, and $q_2 \approx$ qualitative data; [1]cost criteria, and [2]benefit criteria

5. HYPOTHETICAL EXAMPLE

In this section, an example for evaluating the MSW disposal alternatives was provided to illustrate our proposed method and approaches. Suppose that a government linked-company (GLC) decided to invest a sum of money for a new municipal solid waste disposal system. Since most of the MSW materials must be landfilled, four possible disposal systems, $\{A_1, A_2, A_3, A_4\}$ may be considered, given as follows: A_1 is a fully sanitary landfilling, A_2 is an incineration with landfilling, A_3 is a recycling material system with landfilling, and A_4 is composting with landfilling. However, the GLC must make a decision according to four criteria, $\{C_1, C_2, C_3, C_4\}$: C_1 is the economic/cost impact analysis, C_2 is the environmental impact assessments, C_3 = is the social-politic impact, and C_4 is the technological maturity of the systems. Since the nature of the MSW problems is very complicated, a multi-criteria consideration, and involves several interested parties; a single decision maker is not possible. Therefore, the data input from different sources and different points of view was utilised which consisted of the multi-category stakeholders, including government representatives, NGOs, experts as well as business entities who are involved directly with MSW disposal management. Four stakeholders (s^1, s^2, s^3, s^4) are involved and give their assessment based on their experience and their expertise. The stakeholders are from government agencies (s^1), experts (s^2), business entities (s^3), and non-government organisations (NGOs)(s^4). Thus, the decision matrix, $A = (a_{ij})_{n\times m}\ (i, j = 1,2,3,4)$, and their criteria, sub-criteria and computational procedure are detailed below.

i. Arrange the hierarchical structure of MSW disposal alternatives as in Figure 4.
ii. Evaluate the relative weight by conflicting approach where positive and negative aspects are denoted by (a_{ij}^+, a_{ij}^-) notation, respectively. For each criterion, the relative weight of four stakeholders (s^1, s^2, s^3, s^4), were s^1 = 0.4, s^2 = 0.25, s^3 = 0.20 and s^4 = 0.15, respectively. Thus, sum up all the scores corresponding to its criteria as in Table 3.
iii. Calculate the performance score of the sub-criterion by TFNs given in Table 2 and shown in Table 4 and 5.
iv. Obtain the aggregated fuzzy weights of criterion and fuzzy decision matrix as in Table 6
v. Establish the normalised fuzzy decision matrix in Table 4 as in Table 6 (second and last rows).

Table 3: The importance weight of the criteria

Criteria	Stakeholders			
	s^1	s^2	s^3	s^4
C_1	(MH, L)	(MH, ML)	(M, M)	(VH, VL)
C_2	(H, VL)	(M, ML)	(M, MH)	(MH, L)
C_3	(MH, ML)	(VH, L)	(M, MH)	(ML, H)
C_4	(M, ML)	(MH, L)	(ML, H)	(M, ML)

Note: (a_{ij}^+, a_{ij}^-) ≈ ('positive aspect', 'negative aspect')

Table 4: The rating of the four disposal systems by stakeholders under quantitative criteria

	Criteria	
System	C_1 (in million RM)	C_4 (in years)
A_1	(9,10,12)	(50, 60, 80)
A_2	(20,24,25)	(40,60,70)
A_3	(15,18,20)	(30,40,60)
A_4	(17,18,22)	(25,30,45)

Note: RM is Ringgit Malaysia; US$1 = RM3.20(approx.)

vi. Determine the FPIS and FNIS by constructing the weighted fuzzy performance matrix as shown in Table 7.
vii. Calculate the distance of each alternative from FPIS and FNIS, respectively, using vertex method.
viii. Calculate the performance index based on the FIS, as in Table 8 (last column)
ix. Determine the ranking by descending order; i.e. greater performance index (PI) is preferred as an alternative solution.

Table 5: The rating of the four disposal systems by stakeholders under qualitative criteria

Criteria	Systems	Stakeholders			
		s^1	s^2	s^3	s^4
C_2	A_1	(F, MP)	(MG, F)	(G, VP)	(MG, P)
	A_2	(VG, VP)	(G,MP)	(F, MG)	(VG, P)
	A_3	(MG, P)	(G, P)	(F, MP)	(F, MG)
	A_4	(P, G)	(MP, G)	(MG, MP)	(G, P)
C_3	A_1	(MP, MG)	(F, MP)	(MG, F)	(G, P)
	A_2	(F, MG)	(MP, G)	(G, MP)	(VG, VP)
	A_3	(G,P)	(G, MP)	(MG, P)	(F, MP)
	A_4	(F, MP)	(MP,G)	(MG, P)	(P, MG)

Note: (a_{ij}^{+}, a_{ij}^{-}) ≈ ('positive aspect', 'negative aspect')

Table 6: The fuzzy decision matrix and fuzzy weights of four alternatives

	C_1	C_2	C_3	C_4
A_1	(0.520,0.600,0.640)	(0.0,0.169,0.380)	(0.432,0.649,0.838)	(0.625,0.750,1.0)
A_2	(0.0,0.0400,0.200	(0.0,0.113,0.296)	(0.473,0.649,0.797)	(0.50,0.7500,0.875)
A_3	(0.200,0.280,0.400)	(0.056,0.239,0.465)	(0.622,0.838,1.0)	(0.375,0.500,0.750)
A_4	(0.120,0.280,0.320)	(0.268,0.465,0.648)	(0.297,0.486,0.689)	(0.313,0.375,0.563)
Weight	(0.560,0.645,0.795)	(0.550,0.630,0.763)	(0.448,0.440,0.640)	(0.380,0.383,0.570)

Table 7: The weighted fuzzy performance matrix

	C_1	C_2	C_3	C_4
A_1	(0.291,0.387,0.509)	(0.0,0.106,0.290)	(0.194,0.285,0.536)	(0.238,0.287,0.570)
A_2	(0.0,0.026,0.159)	(0.0,0.071,0.226)	(0.212,0.285,0.510)	(0.190,0.287,0.499)
A_3	(0.112,0.181,0.318)	(0.031,0.151,0.354)	(0.278,0.369,0.640)	(0.143,0.191,0.428)
A_4	(0.067,0.181,0.254)	(0.147,0.293,0.494)	(0.133,0.214,0.441)	(0.119,0.143,0.321)

Table 8: The distance measurement and the performance index

	d^*	d^-	PI
A_1	2.816	1.345	0.316
A_2	3.210	0.938	0.216
A_3	2.981	1.182	0.275
A_4	3.099	1.034	0.242

As seen in Table 8, the best alternative is A_1 = 0.316, followed by A_3 = 0.275 and A_4 = 0.242, and the last alternative is A_2 = 0.216, which gives the ranking of $A_1 \rangle A_3 \rangle A_4 \rangle A_2$, where the symbol '〉' means 'is superior or preferred to'

6. DISCUSSION AND CONCLUSION

Since MCDM problems generally involve uncertainty, it is important to incorporate conflicting approaches to deal efficiently with any proposed solution. Thus, this paper introduces a new concept of evaluation approach which is quiet different from the usual points of view. It has utilised both positive and negative aspects simultaneously in the judgement process and the performance index was calculated efficiently in a proposed hybrid model. Both model and approach demonstrates the great advantages from two broad perspectives. First, the model is successful in dealing with situations which are too complex or too ill-defined in terms of input data, and thus can give a reasonable description in terms of quantitative expression. Second, the approach provides the comprehensive evaluation towards the precise decision. Moreover, other advantages (Zamali et al. 2008) that could be utilised are as follows:

- It offers a comprehensive evaluation the so-called 'conflicting approach', which considers both positive and negative aspects simultaneously in the overall decision processes;
- It can integrate opinion and devise a complex decision-making system into a simple element of a hierarchical system;
- It takes into consideration not just tangible but also intangible criteria;
- It allows the DMs to incorporate both 'hard data' and less quantifiable elements such as judgements, feelings and experiences;
- It can set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered simultaneously;
- It can generate numerical priorities from the subjective knowledge in the estimation of directly assigned judgements;
- It can eliminate the subjective component of experts'/stakeholders knowledge, and can be expressed in linguistic terms.

Based on the new approach and the proposed model, it is clearly seen that the consideration for both positive and negative aspects in the evaluation process is more comprehensible in concept and very promising in a final decision perspective. It is expected that the conflicting approach using the proposed model in this paper may become a starting point for developing other potential applications in the near future.

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