Journal of Sustainability Science and Management
Volume 6 *Number* 1, June 2011: 139-147
ISSN: 1823-8556

DETERMINATION OF WEIGHT FOR LANDFILL-SITING CRITERIA UNDER CONFLICTING BIFUZZY PREFERENCE RELATION

LAZIM ABDULLAH*, NUR SYIBRAH NAIM AND ABD FATAH WAHAB

Department of Mathematics, Faculty of Sciences and Technology, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia.

**Corresponding author: lazim_m@umt.edu.my*

Abstract: Selection of suitable landfill sites becomes more relevant as a community population increases. Potential landfill sites must be carefully screened to ensure the chosen site meets all engineering, geological, and regulatory criteria. However, choosing the right criteria and its contributions toward landfill-siting selection are very much conflicting notions and far from conclusive. Weights for landfill-siting criteria are seen as less tangible and may be seen differently. This paper investigates the determination of weights for ten criteria in landfill-siting problems using a conflicting preference approach. Three landfill management experts from three different municipalities in Kedah, Malaysia were interviewed to elicit conflicting judgements data over the criteria of landfill-site selection. The judgement data were aggregated using the proposed five-steps of conflicting bifuzzy preference relations. In this investigation, it is found that the criteria of Political Issues gained the highest weight followed by the criterion of Land Use. The results offer a good input to policy makers in landfill management, especially in a situation where weight-determination solutions are needed.

KEYWORDS: Landfill-siting, Conflicting bifuzzy preference, Intuitionistic fuzzy sets, Criteria weights, Decision-making

Introduction

The decision to locate a municipal sanitary landfill involves intricate problems as vastly qualitative criteria, together with quantitative criteria, need to be accounted. The qualitative and quantitative criteria such as economic factors, engineering causes and social aspects are intertwined in a process of positioning landfills. Landfill location sometimes become a highly political issue and needs to be handled amicably without destabilising harmonious social structure. Potential landfill sites must be carefully screened to ensure that the chosen site meets all engineering, geological, and regulatory specifications. Prior to locating a new landfill, the volume of landfill space that is required for the community should be estimated. These estimates are made by considering a variety of criteria such as the population size, predicted growth and the amount of disposal generated per person in the community. The site chosen for a landfill should provide sufficient capacity to accept waste from the community for up to a certain number of years to make the investment economically feasible. Thus it is truly important to resolve the suitability of landfill-siting criteria that must be perfectly chosen for the optimum landfill siting. Siting a landfill is a challenging task, as most of the time various controversial criteria should be considered (Gemitzi *et al.*, 2007). Of the many criteria, Banar *et al.* (2007), for example, considered legislative restrictions as one of the important criteria. The other basic conditions that should be considered are the suitability of the landfills to be located and the minimum distance between a sanitary landfill and a residential area. No sanitary landfill can be constructed at places where the danger of flooding exists and it should be located at a place where it can be easy to access (the road condition) under all weather conditions. Obviously, there are many criteria could be considered, especially for municipalities in materialising the chosen sites that are acceptable, not only by residents but also fulfilling all environmental engineering conditions. It is truly important for a municipality to consider all criteria so that site does not create

Received: 22 July 2010 / Accepted: 12 October 2010

major problems and will not agitate residents. It is rather true that consistent decision-making provisions of the potential landfill areas are based on a variety of criteria (Sener *et al.*, 2006).

Prescribing criteria that can fulfill all corners of human needs is a daunting task indeed. Of numerous criteria proposed by many researchers, the criteria proposed by Javaheri *et al.* (2006) combined with Chang *et al.* (2008) are deemed suitable to meet with Malaysian circumstances due to common climatic conditions as well as geographical location. The criteria and their descriptions are given in Table 1.

It is a typical move for municipal solid-waste landfill management to have a consideration for the above criteria in determining the best landfill site. However, the listed criteria need to be further examined due to their unequal contributions toward landfill-siting choices. Perhaps humanistic criteria should be weighted more than other criteria. In other words, every criterion has a distinct property function and surely carries a different weight. In order to find the best criteria of landfill-site selection, it is imperative to pay attention to weights of the criteria. Over the last 25 years, a number of approaches have been developed to rank, evaluate, and prioritise the criteria that sometimes could be very difficult to quantify (Lahlou, 1991). Obviously, some of the criteria are considered more important than the others but which is the most important is still a vague and subjective matter.

Weight and Evaluation

The evaluation based on weights in the decision-making process is relatively new in landfill management. This type of evaluation is moving in tandem with the development of multi-criteria decision-making and has become a subject which has interested the scientific community for the last few decades (Zeleny, 1982). For example, a study in Regina, Canada shows that the criteria such as public interest, agriculture, hydrogeology, transport, land use, heritage, cost, political and wildlife are considered in landfill evaluation. The best potential landfill sites are ranked according to their total gained weight (Cheng *et al.* , 2003). Wang *et al.* (2009) consider economic factors in calculating criteria weights using the analytical hierarchy process and built a hierarchy model for solving the solid-waste landfill site-selection problem in Beijing, China. Kontos *et al.* (2005) evaluate the suitability of the study region in order to optimally site a landfill. Multiple criteria were conceptualised as hierarchical structure problems and evaluation criteria were based on relative importance weights of the evaluation criteria. Estimated weights were again computed using the analytic hierarchy process. In another study, Ersoy and Bulut (2009) applied an analytic hierarchy process to select the most suitable solid-waste disposal site for municipal waste in the city among the alternative candidate sites. These researches are profoundly using weight of criteria derived from an analytic hierarchy process method in selecting the optimal landfill sites. Despite the vast research on criteria weight, there remain many open issues on how weights could be possibly determined. Instead of using a hierarchical structure analysis, the present study proposes a new preference in conflicting environment to determine weight of landfill-siting criteria.

In the presence of multiple criteria, a conflict may occur in deciding which criterion is more important than another. For example, some people firmly say that geomorphologic is the most influential criterion but this choice may receive unwelcoming response from other parties. Perhaps another group of people also agree the need of geomorphologic criterion but with a moderate tone. Thus, solving these conflicting situations must be justified by means of conflicting considerations. It is a normal practice to make a decision just solely on account of the positive degree of a criterion. For example, to decide the best mobile phone, a list of positive aspects of criteria is considered without thinking that the negative aspects are equally important. In many real-life situations, preferences or judgements become more comprehensive if negative and positive degrees are considered concurrently. The new preference relation which is named as conflicting bifuzzy preference relation (CBPR) is proposed by introducing some modifications on

Table 1. Criteria in landfill siting.

Criteria	Description
Humanistic	Distance from residential areas, park and recreational areas (health effect, safety, public acceptance and public image).
Hydrology	Distance from river would be located in an area where the groundwater is deep below the ground surface, regardless of groundwater quality. A water-quality zone is suitable for the development of a sanitary-landfill facility and must located far from drinking-water sources.
Transportation	Suitable highway access and no required upgrading to the access roads and would not cause hazardous road conditions to existing vehicle and pedestrian traffic during the transportation of solid waste.
Agriculture	Disruptions of farm operations.
Geomorphologic	A sanitary landfill site would not be located over unstable areas. This could include collapsing soils, steep slopes or cavernous. The soils must with a low permeability (like a clay-type soil where liquids will move through it at a slower rate than a sand-type soil, for example).
Land Use	A preferred sanitary landfill site would have short distances to connect to existing utilities, including power, water, sewer, telephone, and other required utilities A preferred sanitary landfill site would have enough site capacity. The site would not impact local airports including bird hazards to aircraft.
Economic/Financial	The consequences to the financial management such as land cost, operating cost, capital cost.
Wildlife Conflicts	A preferred sanitary landfill site would limit impact adverse to wildlife resources.
Political Issues	Government, provincial, city authorities and local jurisdictions supports.
Pollution	Water contamination, site air contamination and noise concern.

intuitionistic fuzzy preference relations. This new insight is actually a hybridisation of intuitionistic fuzzy set proposed by Atanassov (1986) and preference relation suggested by Xu (2007b). The conflicting decision-making environments have been successfully used by Zamali *et al.,* (2008a; 2009b) to evaluate qualitative attributes using equilibrium linguistic bifuzzy preference relations. This paper is not intended to explore details of these theoretical explanations. Rather, it provides the application of conflicting decision-making in criteria weight of landfill siting. In other words, the conflicting idea paves the way to a new decision-making model based on intuitionistic fuzzy sets and preferences. Therefore, the aim of this paper is to weigh the criteria in landfill siting in accordance with the preferences based on a new conflicting bifuzzy theory. This study attempts to solve a conflict in selecting which criterion is the best to be considered in locating the best landfills in the targeted area.

Preliminaries

To make this paper self-contained, the following definitions are presented. Definition 1 views the general frame of Multi-Criteria Decision-Making (MCDM).

Definition 1. Multi-Criteria Decision-Making (Liu and Wang (2007).

Let A be a set of alternatives and let C be a set of criteria, where $A = \{A_1, A_2, ..., A_m\}$, $C = \{C_1, C_2, ..., C_n\}$, respectively. A MCDM problem can be concisely expressed in matrix format as:

	C_1	C_2	$\cdots$	C_n
A_1	x_{11}	x_{12}	$\cdots$	x_{1n}
A_2	x_{21}	x_{22}	$\cdots$	x_{2n}
$\vdots$	$\vdots$	$\vdots$		$\vdots$
A_m	x_{m1}	x_{m2}	$\cdots$	x_{mn}

A general decision problem with m alternatives A_i ($i = 1,..., m$) and n criteria c_j ($j = 1,..., n$) can be concisely expressed as: $D = [x_{ij}]$ and $W = (w_j)$, where $i = 1,...,m$ and $j = 1,...,n$. Here D is referred to as the decision matrix (where the entry x_{ij} represents the rating of alternatives A_i with respect to criterion C_j), and W as the weight vector (where w_j represents the weight of criterion C_j). Assume that the characteristics of the alternative A_i are presented by the intuitionistic fuzzy set (IFS) shown as follows: $A_i = \{(C_1, \mu_{i1}, \upsilon_{i1}), ..., (C_n, \mu_{in}, \upsilon_{in})\}$, $i = 1,2 ...,m$. Where μ_{ij} indicates the degree to which the alternative M_i satisfies criterion C_j, υ_{ij} indicates the degree to which the alternative A_i does not satisfy criterion C_j where $i = 1,2 ...,m$, $i = 1,2 ...,n$. Decision-making process stemmed from the well-known fuzzy sets theory.

Definition 2. Fuzzy Sets. Zadeh (1965).

Let X be a space of points (object), with a general element of X denoted by.Therefore, $X \{x\}$. A fuzzy set (class) in is characterised by a membership (characteristic) function $f_A(x)$ which associates with each points in X a real number in the interval [0,1] with the value of $f_A(x)$ at representing the "grade of membership" of x in A. Thus, the nearer the value of $f_A(x)$ to unity, the higher the grade of membership of x in A. Specifically, a fuzzy set on a classical set X is defined as follows:

$$A = \{(x, \mu_A(x)) \mid x \in X\} \quad (1)$$

Twenty years later, Atanassov (1986) extended this Zadeh' idea by using the concept 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 to another with the sum of these two grades being not greater than one (Deschrijver and Kerre, 2007). This idea, which is a natural generalisation of a standard fuzzy set, seems to be useful in modelling many real-life situations (Grzegorzewski and Mrowka, 2005). It was derived from the capacity of humans to develop membership functions through their own natural intellect and understanding. It also involves contextual and semantic knowledge about an issue. It can also entail linguistic truth values about this knowledge.

Definition 3. Intuitionistic fuzzy set (Atanassov, 1986).

An intuitionistic fuzzy set, A on a universe X is defined as an object of the following form

$$A = \{(x, \mu_A(x), \upsilon_A(x)) \mid x \in X\} \quad (2)$$

where the functions $\mu_A : X \rightarrow [0,1]$ define the degree of membership and $\upsilon_A : X \rightarrow [0,1]$ the degree of non-membership of the element $x \in X$ in A, and for every $x \in X$, $0 \leq \mu_A(x) + \upsilon_A(x) \leq 1$. Obviously, each ordinary fuzzy set may be written as $\{(x, \mu_A(x), 1 - \upsilon_A(x)) | x \in X\}$. He also extended the intuitionistic fuzzy sets by adding the intuitionistic index which exists because of the uncertainty of knowledge. Then, with the introduction of hesitation degree / intuitionistic index, an intuitionistic fuzzy set A in X may be represented as:

$$A = \{(x, \mu_A(x), \upsilon_A(x), \pi_A(x)) \mid x \in X\} \quad (3)$$

with the condition. This intuitionistic index turns the intuitionistic fuzzy sets into complementary. Therefore,

$$\pi_A(x) = 1 - \mu_A(x) - \upsilon_A \quad (4)$$

Fuzzy sets and intuitionistic fuzzy sets approaches have inspired a new idea. Zamali *et al.* (2008a) introduced the new theoretical concept called 'conflicting bifuzzy sets' (CBFS). It is just a small contribution to the condition proposed by Atanassov (1986). The extension from IFS concepts and Yin Yang theory (Zhang and Zhang, 2004) motivate the Definition 4.

Definition 4. Conflicting bifuzzy set (Zamali *et al.*, 2008).

Let a set X be fixed. A conflicting bifuzzy set A of X is used and object has the following form:

$$A = \{< (x,\mu_A(x),\upsilon_A(x)) > | x \in X\} \quad (5)$$

where the functions $\mu_A : X \rightarrow [0,1]$ represents the degree of positive x with respect to A and $x \in X \rightarrow \mu_A(x) \in [0,1]$, With the new condition $0 < \mu_A(x) + \upsilon_A(x) \leq 1 + \xi$ by replacing the intuitionistic condition. The functions $\upsilon_A : X \rightarrow [0,1]$ represent the degree of negative x with respect to A and $x \in X \rightarrow \upsilon_A(x) \in [0,1]$. The ξ represents the small conflict value which exists only when values of bifuzzy is larger than one. From intuitionistic bifuzzy the unknown value $\pi = 1 - \mu - \upsilon$ while for conflicting bifuzzy the small conflict value is $|\xi| = 1 - \mu - \upsilon$, for all $0 \leq \xi \leq 1$. The conflicting bifuzzy can only be considered in certain cases when it is out of intuitionistic condition.

In decision-making there are many available procedures to cater to selection processes. Score function is one of the selective procedures for selection and ranking specifically for complementary judgement. This model was created by Wang *et al.* (2008) in fuzzy multi-criteria decision-making based on vague sets. This new score function developed as a result of some insignificant element detected in the earlier formula from Chen and Tan (1994) when incriminating fuzzy data.

Nowadays, score function has been adopted into ranking and selection in intuitionistic fuzzy decision-making. The traditional score function is given as

$$\Delta b_{ij} = \mu_{ij} - \upsilon_{ij} \quad (6)$$

where Δb_{ij} is the score of b_{ij}, and $\Delta b_{ij} \in [-1,1]$. The larger the score, the greater the intuitionistic fuzzy values b_{ij}.

This research uses new score function for ranking and selection process by applying intuitionistic fuzzy sets. This score function is reasonably used in judgement due to its property of considering the unknown part (π_{ij}).

Definition 5. Score function of intuitionistic fuzzy sets (Wang *et al.*, 2008).

Let $x_{ij} = (\mu_{ij}, \upsilon_{ij})$ be an intuitionistic fuzzy value. For $\mu_{ij}, \upsilon_{ij} \in 1, \mu_{ij} + \upsilon_{ij} \leq 1$. The score of x_{ij} can be evaluated by the score function S defined as,

$$S(x_{ij}) = \mu_{ij} - \upsilon_{ij} - \frac{1 - \mu_{ij} - \upsilon_{ij}}{2}$$

$$= \frac{3\mu_{ij} - \upsilon_{ij} - 1}{2} . \quad (7)$$

is (x_{ij}) the score function of x_{ij}, and $S(x_{ij}) \in [-1,1]$. The greater the value of $S(x_{ij})$, the higher the degree of appropriateness that alternatively satisfies some criteria.

Szmidt and Kacprzyk, (2002) generalised the fuzzy preferences in relation to the intuitionistic fuzzy preference relation. Xu (2007a) introduced the concept of intuitionistic preference relation as a combination of IFS and fuzzy preference relations.

Definition 6. Intuitionistic preference relation (Xu, 2007a).

An intuitionistic preference relation B on the set X is represented by a matrix $B = (b_{ij}) \subset X \times X$ with $b_{ij} = <(x_i,x_j),\mu(x_i,x_j),\upsilon(x_i,x_j)>$ for all $i,j = 1,2,...,n$. For convenience, we let $b_{ij} = (\mu_{ij},\upsilon_{ij})$, for all $i,j = 1,2,...,n$ where b_{ij} is an intuitionistic fuzzy value, composed by the certainty degree μ_{ij} to which x_i is preferred to x_j and certainty degree υ_{ij} to which x_i is non-preferred to x_j, and $\pi = 1 - \mu_{ij} - \upsilon_{ij}$ is interpreted as the uncertainty degree to which x_i is preferred to x_j where μ_{ij}, υ_{ij} satisfy $0 \leq \mu_{ij} + \upsilon_{ij} \leq 1$. The concept of intuitionistic preference relations and fuzzy preference relations lead into the proposed conflicting bifuzzy preference relations.

Definition 7. Conflicting bifuzzy preference relations.

A conflicting bifuzzy preference relation P is a bifuzzy subset of A x A which is characterised by the following membership function:

$$\mu_{ij}(A_i, A_j) = \begin{cases} 1, & \text{if } A_i \text{ is positive definitely preferred to } A_j, \\ c > d, & \text{if } A_i \text{ is positive slightly preferred to } A_j, \\ c = d, & \text{if there is no preference (indifference)}, \\ d > c, & \text{if } A_j \text{ is positive slightly preferred to } A_i, \\ 0, & \text{if } A_j \text{ is positive definitely preferred to } A_i, \end{cases}$$

and

$$\upsilon_{ij}(A_i, A_j) = \begin{cases} 1, & \text{if } A_i \text{ is negative definitely preferred to } A_j, \\ c < d, & \text{if } A_i \text{ is negative slightly preferred to } A_j, \\ c = d, & \text{if there is no preference (indifference)}, \\ d < c, & \text{if } A_j \text{ is negative slightly preferred to } A_i, \\ 0, & \text{if } A_j \text{ is negative definitely preferred to } A_i, \end{cases}$$

Definition 8. Condition of conflicting bifuzzy (Imran *et al.*, 2008).

Let $A = \{a_1,a_2,...,a_n\}$ be a finite set of alternatives and $B = \{(b_1,b_2,...,b_m\}$ the set of DMs. X is a matrix of conflicting bifuzzy preferences relation represented by $X = (x_{ij})_{nxn} \subset A \text{ x } A$ for all $x_{ij} = <(a_i,a_j),\mu(a_i,a_j),\upsilon(a_i,a_j)>$ for all $i, j = 1,2,...,n$ where x_{ij} is an conflicting bifuzzy value, composed by the certainty degree μ_{ij} to which a_i is positively preferred to a_j and certainty degree υ_{ij} to which a_i is negatively preferred to a_j, and $0 < \mu_A(a) + \mu_A(a) < 1 + \xi$, $\mu_{ij} = \upsilon_{ij}$, $\upsilon_{ij} = \mu_{ij}$.

For conflicting bifuzzy, the condition is not restricted to 1 or less than 1, as to discard the intuitionistic fuzzy set constraints. Details of these arguments can be seen from Imran *et al.* (2008). The addition value for positive preference and negative preference can be greater than 1 but never exceed 2. There are some relations and operations which are very important to aggregate conflicting bifuzzy preference relations.

Weight of Criteria under Conflicting Preference

Aggregation of criteria weight is executed using the conflicting bifuzzy preference relations. Membership functions of the newly-constructed bifuzzy preference relation which accounted both positive and negative judgement are the input for the approach. This section presents five steps of the conflicting bifuzzy preference relations approach in determining weight for each criterion.

Step 1: Let $A = \{a_1,a_2,...,a_n\}$ be a finite set of alternatives and $B = \{(b_1,b_2,...,b_m\}$ the set of decision-makers (DMs). Let $\omega = \{(\omega_1,\omega_2,...,\omega_m\}$ be the weight vector of DMs. The DM $b_k \in D$ provides his/her conflicting bifuzzy preference for each pair of alternatives, and constructs conflicting bifuzzy preference relations.

Step 2: Use the conflicting bifuzzy fuzzy arithmetic averaging operator to aggregate all $x_{ij}^{(k)}$ ($k = 1,2,...,n$) for getting the averaged conflicting bifuzzy values of the alternatives x_i over all the other alternatives.

$$x_i^{(k)} = \frac{1}{n}\sum_{j=1}^{n} x_{ij}^{(k)} \quad i, j = 1,2,..., n \tag{8}$$

Step 3: Use the score function (7) to aggregate all $x_i^{(k)}$ ($k = 1,2,...,m$) corresponding to m DMs into a collective conflicting bifuzzy values x_i of all the alternatives a_i over all the other alternatives.

Step 4: Normalise the matrix and aggregate the criteria weight. The normalised value is,

$$x_i^{(k)} = \frac{x_{ij}^{(k)}}{\sum_{i=1}^{n} x_{ij}^{(k)}}, \quad i, j = 1,2,..., n \tag{9}$$

Step 5: Aggregated the priority weights of each criteria ω_i, where the ω_i denotes the priority weight of criteria i, n represents the number of criterion and $\sum_{i=1}^{n} \omega = 1$.

$$\omega_i = \frac{1}{n}\sum_{k=1}^{m} x_{ij}^{(k)}, \quad i, j = 1,2,..., n. \tag{10}$$

Weight of Landfill-Siting Criteria: A Case Study

This study selects three landfills in Kedah to test the decision-making model. Data were supplied by three environmental officers from three town municipalities in Kedah, Malaysia. The experts need to rate in nine linguistic terms from extremely poor to extremely good over the ten criteria of landfill siting. The linguistic terms and their respective intuitionistic fuzzy membership can be seen in Table 2.

The ten preference criteria were Political Issues (C_9), Land Use (C_6), Wildlife Conflicts(C_8), Hydrology (C_2), Transportation (C_3), Pollution(C_{10}),

Table 2. Intuitionistic linguistic term.

Intuitionistic linguistic term	Membership $[\mu_{ij}, \upsilon_{ij}]$
Extremely poor	[0.1,0.9]
Very poor	[0.2,0.8]
Poor	[0.3,0.7]
Slightly poor	[0.4,0.6]
Fair	[0.5,0.5]
Slightly good	[0.6,0.4]
Good	[0.7,0.3]
Very good	[0.8,0.2]
Extremely good	[0.9,0.1]

Geomorphologic(C_4), Humanistic(C_5), Agriculture (C_1) and Economic/Financial (C_7). Data were computed using the proposed conflicting bifuzzy preference relations. In this experiment, a decision has to be made in establishing weight of the landfill-siting criteria according to experts' preferences. Weighted criteria from the preferences represent the importance of the criteria in landfill siting. The decision process adheres to the following steps.

Step 1:

The landfill-siting criteria are divided into ten, $a_i(i = 1,2,...,10)$ with respect to their municipal solid-waste expert decision-maker's assessment and three DM's $b_k(k = 1,2,3)$ have been set up to provide assessment information on $a_i(i = 1,2,...,10)$. The DM's $b_k(k = 1,2,3)$ provide conflicting bifuzzy preferences value for each pair of alternatives and construct the conflicting bifuzzy preference relations matrix.

$$X^{(k)} = \left(x_{ij}^{(k)}\right)_{10\times10} \quad \left(x_{ij}^{(k)} = \left(u_{ij}^{(k)}, \upsilon_{ij}^{(k)}\right) i, j = 1,2,...10; k = 1,2,3\right),$$

Step 2:

Use the conflicting bifuzzy fuzzy arithmetic averaging operator to aggregate all $x_{ij}^{(k)}(k = 1,2,3)$ for obtaining the averaged conflicting bifuzzy values of the criteria x_i over all the other criteria:

For $X^{(1)}$:

$$x_1^{(1)} = (0.5500,0.5700),\ x_2^{(1)} = (0.5200,0.5100),\ x_3^{(1)} = (0.5400,0.5700),\ x_4^{(1)} = (0.4700,0.5200),$$
$$x_5^{(1)} = (0.5400,0.5500),\ x_6^{(1)} = (0.5700,0.5200),\ x_7^{(1)} = (0.5100,0.5600),\ x_8^{(1)} = (0.5900,0.5500),$$
$$x_9^{(1)} = (0.5600,0.5000),\ x_{10}^{(1)} = (0.5200,0.5200).$$

Step 3:

Use the score function to aggregate all $x_{ij}^{(k)}$ ($k = 1,2,3$) ensuing to m DM's into a collective conflicting bifuzzy values x_i of the entire criteria

For $X^{(2)}$:

$$x_1^{(2)} = (0.5200,0.5200),\quad x_2^{(2)} = (0.5300,0.5300),\quad x_3^{(2)} = (0.5000,0.4900),$$
$$x_4^{(2)} = (0.5400,0.5400),\quad x_5^{(2)} = (0.5200,0.5300),\quad x_6^{(2)} = (0.5300,0.5400),$$
$$x_7^{(2)} = (0.5100,0.5100), x_8^{(2)} = (0.4900,0.4600),\quad x_9^{(2)} = (0.5100,0.5200),$$
$$x_{10}^{(2)} = (0.5200,0.5300).$$

For $X^{(3)}$:

$$x_1^{(3)} = (0.5200,0.5500),\quad x_2^{(3)} = (0.5600,0.5100),\quad x_3^{(3)} = (0.6100,0.6100),$$
$$x_4^{(3)} = (0.5700,0.6300),\quad x_5^{(3)} = (0.5500,0.5800),\quad x_6^{(3)} = (0.5600,0.5800),$$
$$x_7^{(3)} = (0.5300,0.5300),\quad x_8^{(3)} = (0.5400,0.5500),\quad x_9^{(3)} = (0.5900,0.4900),$$
$$x_{10}^{(3)} = (0.5600,0.5600).$$

a_i over all the other criteria. Thus collective conflicting bifuzzy values are,

$$X^{(1)} = (0.0400,0.0250,0.0025,-0.0550,0.0350,0.0950,-0.0150,0.1100,0.0900,0.020)$$
$$X^{(2)} = (0.0200,0.0300,0.0050,0.0400,0.0150,0.0250,0.0100,0.0050,0.0050,0.0150)$$
$$X^{(3)} = (0.0050,0.0850,0.1100,0.0400,0.0350,0.0500,0.0300,0.0350,0.1400,0.0600).$$

Step 4:

Normalise the matrix and aggregate the criteria weight. Thus decision-makers' normalised values are,

$$X^{(1)} = (0.1081,0.0676,0.0676,-0.1488,0.0946,0.2568,-0.0405,0.2973,0.2432,0.0541)$$
$$X^{(2)} = (0.1176,0.1765,0.0294,0.2353,0.0882,0.1471,0.0588,0.0294,0.0294,0.0882)$$
$$X^{(3)} = (0.0085,0.1441,0.1864,0.0678,0.0593,0.0847,0.0508,0.0593,0.2373,0.1017).$$

Step 5:

Aggregate the priority weights of each criteria ω_i, where the ω_i denotes the priority weight of criteria i, n represents the number of criterion. The weight for each criterion is obtained as,

$$\omega_1 = 0.0781, \omega_2 = 0.1294, \omega_3 = 0.0945, \omega_4 = 0.0515, \omega_5 = 0.0807, \omega_6 = 0.1629,$$
$$\omega_7 = 0.0230, \omega_8 = 0.1287, \omega_9 = 0.1700,\ \omega_{10} = 0.0813$$

Therefore, the weights can be arranged in descending order as

$$\omega_9 \prec \omega_6 \prec \omega_2 \prec \omega_8 \prec \omega_3 \prec \omega_{10} \prec \omega_5 \prec \omega_1 \prec \omega_4 \prec \omega_7$$

Weights of the criteria and importance order can be summarized in Table 3.

In this case study, it was found that the criterion of Political Issue received the highest weight in deciding landfill siting followed by Land Use. At the other end, Economic/Financial criterion recorded the lowest weight.

Conclusion

Issue of unequal contributions among multiple criteria in deciding the best landfill siting has been addressed. The proposed method develops from

Table 3. Weight of criteria.

Criteria	Weight	Importance order
Humanistic (C_5)	0.0781	7
Hydrology (C_2)	0.1294	3
Transportation (C_3)	0.0945	5
Agriculture (C_1)	0.0515	8
Geomorphologic (C_4)	0.0416	9
Land use (C_6)	0.1629	2
Economic/Financial(C_7)	0.0230	10
Wildlife conflicts (C_8)	0.1287	4
Political Issues (C_9)	0.1700	1
Pollution (C_{10})	0.0813	6

intuitionistic preference relation together with a score function prior to normalisation process were intricately blended to determine weights for landfill-siting criteria. The use of score function in conflicting preference relations offer a new dimension for the estimated weights. Positive and negative performance evaluations for the criteria were compromised to reach a decision based on weighted criteria. Of the ten criteria, criterion of Political Issues carried the highest weight followed by the criterion of Land Use. This weight evaluation concludes that political issue was the most influential determinant in landfill-siting criteria, specifically at the studied area. The evaluation also decides that the criterion of financial consequence to management, such as land cost, operating cost and capital cost, was given the least priority. The result gives insight into the importance of the selected criteria in deciding the best landfill siting. It is hoped that the results may offer an opportunity for municipalities to emulate the weighted criteria in landfill-siting selection and help in finding an easy solution. Planning for landfill siting indeed demand comprehensive analysis of the criteria. The application of appropriate tools in decision-making would generate more reliable judgement. It is also suggested that the feasibility of the conflicting bifuzzy preference relations be extended in other decision-making environments.

References

Atanassov, K. T. (1986). Intuitionistic fuzzy sets. *Fuzzy Sets and Systems*, 110: 87 – 96.

Banar, M., Kose, B. M., Ozkan, A. and Poyraz A. I. (2007). Choosing a municipal landfill site by analytic network process. *Environmental Geology*, 52: 747-751.

Chang, N. B., Parvathinathan, G. and Breeden, J. B. (2008). Combining GIS with fuzzy multicriteria decision-making for landfill siting in a fast-growing urban region. *Journal of Environmental Management*, 87: 139–153.

Chen, S. M. and Tan, J. M. (1994). Handling multi-criteria fuzzy decision making problems based on vague set theory. *Fuzzy Sets and Systems*, 67: 163 – 172.

Cheng, S., Chan, C. W. and Huang, G. H. (2003). An integrated multi criteria decision analysis and inexact mixed integer linear programming approach for solid waste management. *Engineering Application in Artificial Intelligence*, 16 (5-6): 543-554.

Deschrijver, G. and Kerre, E. E. (2007). On the position of intuitionistic fuzzy set theory in the framework of theories modeling imprecision. *Information Sciences*, 177: 1860–1866.

Ersoy, H. and Bulut, F. (2009). Spatial and multicriteria decision analysis based methodology for landfill site selection in growing urban regions. *Waste Management and Research*, 27(5):489-500.

Gemitzi, A., Tsihrintzis, V. A., Petalas, C., Voudrias E. and Stravodimos, G. (2007). Combining geographic information system, multicriteria evaluation techniques and fuzzy logic in siting MSW landfills. *Journal of Environmental Geology*, 51:797–811.

Grzegorzewski, P. and Mrowka, E. (2005). Some notes on (Atanassov's) intuitionistic fuzzy sets. *Fuzzy Sets and System*, 156: 492–495.

Imran, C. T., Syibrah, M. N., and Lazim, M. A. (2008). A new condition for conflicting bifuzzy sets based on intuitionistic evaluation, *International Journal of Computational and Mathematical Sciences*, 2(4): 161-165.

Javaheri, H., Nasrabadi, T., Jafarian, M. H., Rowshan, G. R. and Khoshnam H. (2006). Site selection of municipal solid waste landfills using analytical hierarchy process method in a geographical information technology environment in Giroft, Iran. *Jounal Environmental, Health Science Engineering*, 3(3): 177-184.

Kontos, D. T., Komilis, D. P., and Halvadakis, C. P. (2005). Siting MSW landfills with a spatial multiple criteria analysis methodology. *Waste Management*, 25(8): 818-832.

Lahlou, M. (1991). Alternatives evaluation and selection methodology for development and environmental remediation projects. *Doctorial Dissertation*, University of Oklahoma Graduate College, Norman, Oklahoma.

Liu, H. W. and Wang, G. J. (2007). Multi-criteria decision-making methods based on intuitionistic fuzzy sets. *European Journal of Operational Research*, 179: 220–233.

Sener, B., Suzen, M. L. and Doyuran, V. (2006). Landfill site selection by using geographic information systems. *Environmental Geology*, 49: 376–388.

Szmidt, E. and Kacprzyk, J. (2002). Using intuitionistic fuzzy sets in group decision making. *Control and Cybernetics*, 31: 1037-1053.

Wang, G., Qin,L., Li, C., and Chen, L. (2009). Landfill site selection using spatial information technologies and AHP: A case study in Beijing, China. *Journal of Environmental Engineering*, 90(8): 2414-2421.

Wang, Y. M. and Parkan, C. (2008). Optimal aggregation of fuzzy preference relations with an application to broadband internet service selection. *European Journal of Operational Research*, 187: 1476–1486.

Xu, Z. S. (2007a). Intuitionistic preference relations and their application in group decision making. *Information Sciences*, 177: 2363 – 2379.

Xu, Z. S. (2007b). A method for estimating criteria weights from intuitionistic preference relations. In B.Y. Cao (Ed.) *Fuzzy Information and Engineering*, Springer Berlin, Heidelberg.

Zadeh, L. A. (1965). Fuzzy Sets. *Information and Control*, 8(3): 338–353.

Zamali, T., Mohd Lazim, A. and Abu Osman, M. T. (2008b). A novel linguistic aggregation method for group decision making. *The 3rd International Conference on Mathematics and Statistics* (ICoMS-3) Institut Pertanian Bogor, Indonesia.

Zamali, T., Mohd Lazim, A. and Abu Osman, M. T. (2008a). An introduction to conflicting bifuzzy sets theory. *International Journal of Mathematics and Statistics*, 3(08): 86–95.

Zeleny, M. (1982). *Multiple criteria decision making*. New York: Mac Graw Hill.

Zhang, J. and Liu, S. Y. (2006) *A* new score function for fuzzy MCDM based on vague set theory. *International Journal of Computational Cognition*, 4(1): 44-48.

Zhang, W. R. and Zhang, L. (2004). Yin Yang bipolar logic and bipolar fuzzy logic. *Information Sciences*, 165: 265–287.