Managing Bamako's Waste data using Fuzzy-Sets in Decision Making

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SUMMARY: This paper aims to present a fuzzy decision-making approach to deal with the problem of selecting the best technique for Bamako's solid waste management. During recent years, the waste question has become a key strategic consideration in the world in general and especially for developing countries, which have many difficulties for managing their wastes and do not have enough resources to practice recycling at high rate. However, the natures of these decisions are more often complex and unstructured. Usually, many quantitative and qualitative factors (such as quantity, quality, price, available materials, delivery performance, flexibility and distance from waste disposal) must be considered to determine suitable techniques for each place in the city. In this paper, linguistic values are used to assess the ratings and weights for these factors. These linguistic ratings can be expressed in trapezoidal or triangular fuzzy numbers. Then, a hierarchy Multiple Criteria Decision Making (MCDM) model based on fuzzy-sets theory is proposed to deal with the problem of Bamako's solid waste management technique selection. According to the concept of the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), a closeness coefficient is defined to determine the ranking order of all Techniques by calculating the distances to both Fuzzy Positive-Ideal Solution (FPIS) and Fuzzy Negative-Ideal Solution (FNIS) simultaneously. Finally, a case study given as an application example is shown to highlight the procedure of the proposed method at the end of this paper. Results show that the proposed model is very well suited as a tool for making decisions in the case of Bamako's solid waste management techniques.

Keywords: decision making, waste management, linguistic variables, Fuzzy number, factors.

I. INTRODUCTION

With the context of globalization and especially the rural exodus of the local population, West African cities in general and especially those of Mali are experiencing significant increase in their daily production of solid waste, particularly for plastic wastes. Considering the global environmental context, suitable waste management is a priority for the city to minimize solid wastes related problems or risks. Wastes are derived from human activities, thus find the best waste management strategies is a daily problem solving for decision makers.

As the society are becoming more modern, the consumption rate is increasing, that leads to high amount of solid wastes production. Observing that reality, municipalities have to not consider waste as problems but should try to see it as opportunity for developing new products or business types. Thus, the case study of the District of Bamako in Mali is done in this article, in order to propose adapted management methodology based on local realities and constraints.

Effective Municipal Solid Waste (MSW) management techniques for a given locality depend on several qualitative and quantitative factors of complex and often non-structured natures. Thus, the proposed plastic waste management techniques involves several factors such as: acceptance of the project by the population and its participation, education level of the population and information provided, available materials and techniques used.

Lack of reliable data in the sector of MSW (production and management) is a reality in Mali in general and particularly in Bamako, that will make very difficult or unclear to provide accurate information on the exhaustive parameters of the proposed method. Above all, the separation of different types of wastes is not officially made in Bamako, thus, in order to well turn the proposed model, a number of data sets will be used to have some information on the few targeted areas.

By referring to these conditions of lack of data, decision-making is often influenced by the practical uncertainties. In addition, the data are very diverse and varied from one area to another (or from one municipality to another). Thus, it will be much illusory to use the conventional method of probabilistic assessment like "Probit model", taking just two values 1 or 0 depending on whether the event is realized or not. These conventional methods do not allow assessing the fair value of management level for a given area in order to propose the suitable technique that why using method like "Probit model" will overvalued or undervalued the real situation.

Considering (using) fuzzy logic can be a good asset to take into account the lack of data or the vagueness of different situations. This method allows the use of intermediate values between 0 and 1 to well evaluate the diversity of situations in the various environments of the municipalities in the district of

Bamako. For example, if the level of sanitation is seen as variable, it can be: very good, good, poor, etc. The appropriate characterization of this variable will be the use of Fuzzy trapezoidal or triangular number, that allows to assess current situation in more realistic manner. In addition, the assessment of different parameters will lead to the choice of the best management and recycling techniques.

In this paper, extended concept of TOPSIS will be used to develop a methodology for solving waste Management techniques selection issues in Bamako in fuzzy environment.

The paper is organized as follows: Next section introduces the basic definitions and notations of the fuzzy numbers and linguistic variables. In Section 3, a fuzzy decision-making method is presented to cope with Bamako's waste management technique selection problem. Then, the proposed method is illustrated with an application example. Finally, some conclusions are pointed out at the end of this paper.

II. BACKGROUND ON THE DISTRICT BAMAKO

Bamako is the capital of Mali, on the shores of Niger River called Djoliba ("river of blood"), in the southwest of the country. In 2012, the city had 1,926,748 inhabitants, called "Bamakois". Its rate of urban growth (4.8%) is currently the highest in Africa (and the sixth in the world). Bamako is the administrative center of the country, an important river port and commercial center for the entire region. The capital Bamako is erected in the district and sub-divided into six municipalities (Fig. 2) governed by elected mayors.

The city is filling two types of functions: one specific to the regional administration of the state and the other for local interest. The District of Bamako is both an administrative riding of the state located at the same hierarchical level as the region, and a decentralized collectively with legal personality and financial autonomy.

Located in a cuvette surrounded by hills further inland of 7 ° 59 'west longitude and 12 ° 40' north latitude, Bamako extends 22 km from west to east and 12 km from north to south. The District with an area of 267 km ² is grossly composed of two parts:

North: Between the Niger River and Mount Manding in an alluvial plain long of 15 km. This section covers 7000 ha and is narrowed at both ends.

South: The right bank is a site of 12,000 ha.

1,000 kilometers far from Dakar and Abidjan, 850 km from Ouagadougou and 120 km from the Guinean border, Bamako with its impressive population growth has become a crossroads of West Africa (Fig. 1). The city hosts a diverse population, composed of different ethnic groups present in Mali, predominantly rural population in search of work, but also from neighboring countries. Women represent 49.8% of the population. This uncontrolled growth causes significant difficulties in terms of traffic, sanitation (access to safe drinking water, sanitation), pollution, etc. leading to high production of MSW.

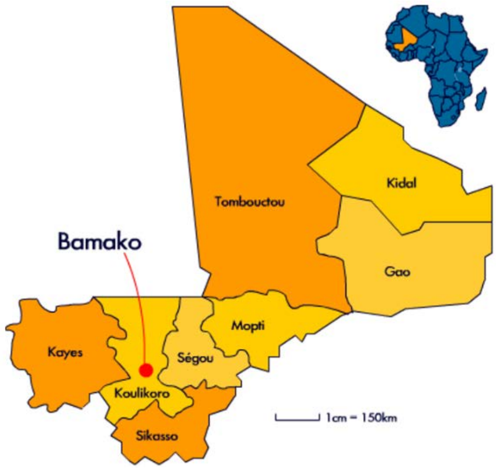

Figure 1. Localisation of Bamako in Mali
Sources: Maliactu.net
(http://maliactu.net/mali-le-mali-compte-desormais-dix-regions/)

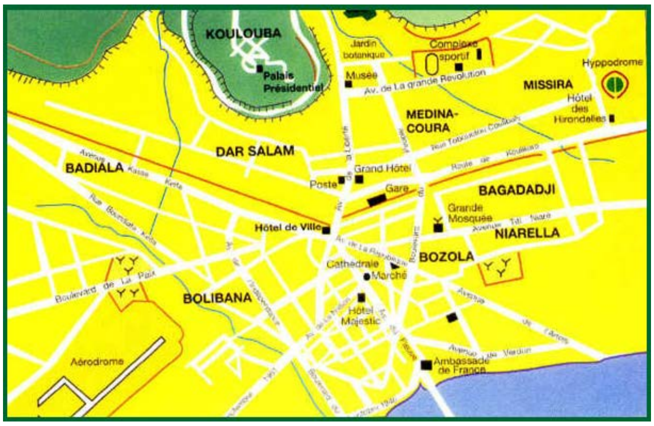

Figure 2. Map of the District of Bamako (Municipalities and Neighborhoods) Source: Amis du Mali https://amisdumali.com/Cartes%20du%20Mali.htm)

2.2 Review and Notification

The submitted abstracts will be reviewed by the Program Committee, and then the corresponding author will be notified of the paper's acceptance or rejection, and oral or poster presentation by 31th March 2010.

If your paper is accepted, you should prepare and send the **final version by 31th May 2010**. You should register your participation to secure your presentation on the final conference program.

III. BACKGROUND ON FUZZY SET THEORY: FUZZY NUMBERS AND

LINGUISTIC VARIABLES.

The circumstances of this study are vague and non-precious for data collection, fuzzy sets theory introduced by **Prof. L.A. Zadeh in 1965** can be used to minimize the impacts coming from data non-accuracy. Below are given some summarizing points that will allow the well understanding of the Fuzzy sets theory.

3.1 A fuzzy set B in the universe of discourse Y is characterized by the membership function μ B which associates to each element y of B, a real number μ B (y) in [0;1] (Kaufmann and Gupta, 1991).

3.2 A fuzzy set B in the universe of discourse Y is convex if and only if : for all a; b in Y and all α in [0;1],

$\mu B(\alpha a + (1-\alpha) b) \geq \min(\mu B(a) ; \mu B(b))$. (Klir and Yuan, 1995).

3.3 The **height** of a fuzzy number is the largest degree of membership attained by any element in that set. A fuzzy set B in the universe of discourse Y is called normalized if the **height of B is equal to 1** (Klir and Yuan, 1995).

3.4 A **Fuzzy number** is a Fuzzy subset in the universe of discourse Y that is **both convex and normal** (Kaufmann and Gupta, 1991). Fig.3 shows an example of Fuzzy number.

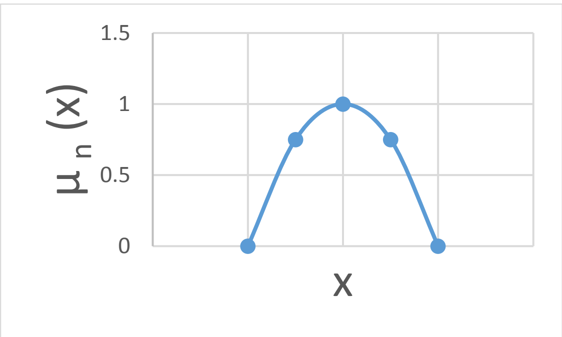

Figure 3. Fuzzy number n

3.5 The α-cut of fuzzy number n is defined as:
$n^{\alpha} = \{a: \mu\, n(a) \geq \alpha,\ a \in Y\}$; where α is in [0;1].
The symbol n^{α} represents a non-empty bounded interval in Y, which can be in that form $n\alpha = [nl\alpha; nu\alpha]$. n_l^{α} and n_u^{α} are respectively the lower and upper bounds of closed interval (Kaufmann and Gupta, 1991; Zimmermann, 1991).
If for all α ∊ [0; 1], $1 \geq n_l^{\alpha} \geq n_u^{\alpha} \geq 0$, then n is called standardized (normalized) positive fuzzy number (Negi, 1989).

3.6 According to (Kaufmann and Gupta, 1991), a positive trapezoidal fuzzy number (PTFN) n can be defined as (n1, n2, n3, n4) with the membership function μn as:

$$\mu_n(x) = \begin{cases} 0 & x \leq n_1 \\ \dfrac{x - n_1}{n_2 - n_1} & n_1 \leq x \leq n_2 \\ 1 & n_2 \leq x \leq n_3 \\ \dfrac{x - n_4}{n_3 - n_4} & n_3 \leq x \leq n_4 \\ 0 & x \geq n_4 \end{cases}$$

The trapezoidal Fuzzy number n can be represented as follow:

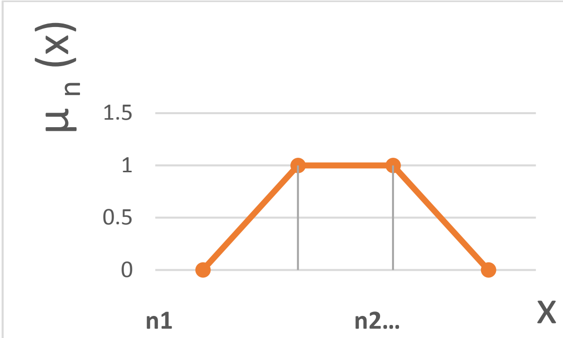

Figure 4. Trapezoidal Fuzzy number n

If n1 = n2, then n is called Triangular Fuzzy number. An example of triangular Fuzzy number is shown in the following figure.

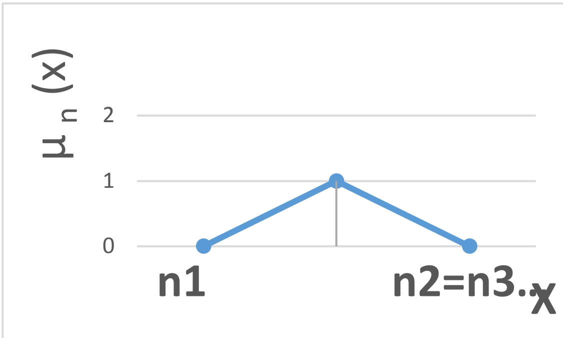

Figure 5. Membership function of triangular Fuzzy number n.

- According to the extension principle of Dubois and Prade (1980), the sum and the subtraction of any two fuzzy numbers are fuzzy numbers; the multiplication of any fuzzy number by a real number is a fuzzy number but the multiplication of any two fuzzy numbers is only an approximate fuzzy number. Given any two positive trapezoidal fuzzy numbers m=(m1, m1, m3, m4) and n=(n1, n2, n3, n4) and a positive real number β, some main operations of fuzzy numbers m and n can be expressed as follows:

$$m + n = (m_1 + n_1;\ m_2 + n_2;\ m_3 + n_3;\ m_4 + n_4)$$

$$m - n = (m_1 - n_1;\ m_2 - n_2;\ m_3 - n_3;\ m_4 - n_4)$$

$$m * \beta = (m_1 * \beta;\ m_2 * \beta;\ m_3 * \beta;\ m_4 * \beta)$$

3.7 A matrix D is called Fuzzy matrix if at least one element is a fuzzy number (Buckley, 1985).

3.8 A linguistic variable is a variable whose values are expressed in linguistic terms (Zimmermann, 1991). According to the same author, to reasonably describe complex situations or not well defined, in conventional quantitative expressions; the concept of linguistic variable is very useful.
For the case study of this project, the following diagram of linguistic variable will be used to measure the weight of our criterion

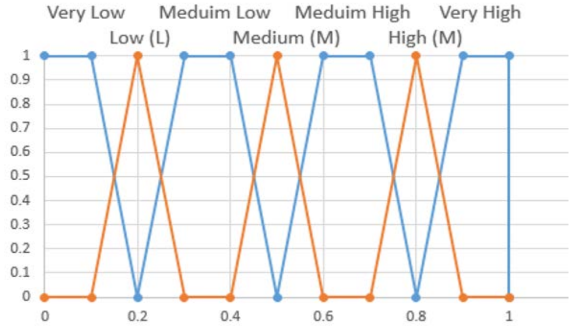

Figure 6. Alterative linguistic variables for importance weight of each criterion.

To have the rating of each alternative according to each criterion, the following graph will be use.

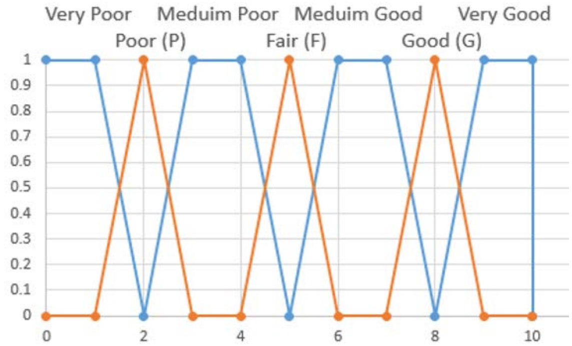

Figure 7. Alterative linguistic variables for ratings.

3.9 Distance between fuzzy numbers and properties: Vertex method will allow to calculate the distance between two fuzzy numbers (Chen, 2000). Let m and n two fuzzy numbers, the distance d (n, m) between n and m is:

- If n and m are trapezoidal

$$d(m,n) = \sqrt{\frac{1}{4}\left[(m_1-n_1)^2 + (m_2-n_2)^2 + (m_3-n_3)^2 + (m_4-n_4)^2\right]}$$

- If n and m are triangular

$$d(m,n) = \sqrt{\frac{1}{3}\left[(m_1-n_1)^2 + (m_2-n_2)^2 + (m_3-n_3)^2\right]}$$

According to the vertex method two fuzzy numbers **n** and **m** are **identical** if and only if d (n, m) = 0. Let **m, n, and p** three fuzzy numbers, according to Chen (2000), **m is closer to n than p** if and only if **d(n,p) ≥ d(m,n).**

IV. PROPOSED METHOD

Consider decision makers with (n) criteria C1, C2…, Cn to evaluate the performance of m possible alternatives A1, A2… Am. Let yij a trapezoidal fuzzy number corresponding to the rating of alternative Ai with respect to the criterion Cj.

A classic multi criteria decision-making problem can be expressed in matrix form as follows:

$$M = \begin{pmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ y_{n1} & y_{n2} & \cdots & y_{nn} \end{pmatrix} \text{ and } V = [V_1 \quad V_2 \quad \ldots \quad V_n]$$

For i=1 to m and j=1 to n; Vj is the weight of the criterion Cj
The approach to extend the TOPSIS method to fuzzy data can besummarize as follows: Generation alternatives and Identification of evaluation criteria; then Choose the linguistic ratings (yij i=1 to m; j=1 to n) of alternatives with respect to criteria and Ascertain the weight of each criteria, allowing to construct the fuzzy decision matrix. Once all these steps done, the fuzzy decision matrix will be normalize. The raw data are normalized to reduce the irregularities with different units of measurements and scale. To avoid complicated normalization formula using complex mathematical operations in a decision process, linear scale transformation is used to transform various criteria scales into comparable scales.
According to the TOPSIS method development, the set of criteria can be divided into benefit criteria (larger the rating correspond to the greater the preference) and cost criteria (smaller the rating lead to greater the preference)[1].Thus the following normalized fuzzy decision matrix will be found:

$$S = [\,S_{ij}\,]_{p*q}$$

B and C are the sets of benefit criteria and cost criteria, respectively, and

$$s_{ij} = \left(\frac{l_j}{h_{ij}}, \frac{l_j}{k_{ij}}, \frac{l_j}{g_{ij}}, \frac{l_j}{l_{ij}}\right); j \in C \text{ or}$$

$$s_{ij} = \left(\frac{l_{ij}}{h_j}, \frac{g_{ij}}{h_j}, \frac{k_{ij}}{h_j}, \frac{h_{ij}}{h_j}\right); j \in B$$

$$h_j = \max_i h_{ij}, j \in B \;;\; l_j = \min_i l_{ij}, j \in C$$

With the benefit (B) and cost attributes (C), actions on criteria can be taken in order to satisfy decision makers' desire by maximizing or minimizing respectively.
The normalization method mentioned above is designed to preserve the property in which the elements Sij are standardized (normalized) trapezoidal fuzzy numbers for any given value of (i, j). By considering the different weight of each criterion, the weighted normalized fuzzy decision matrix can be constructed as follows:

$$U = [\, u_{ij} \,]_{p*q} \; ; i = 1, 2, 3, \ldots, p \text{ and } j = 1, 2, 3, \ldots \ldots, q$$

$$u_{ij} = s_{ij} * v_j$$

Uj represents the importance of the criterion Cj.
At that point, Fuzzy positive-ideal solution (FPIS, P+) and fuzzy negative-ideal solution (FNIS, N-) can determine as:

$$P+ = (P_1, P_2, P_3, \ldots\ldots, P_n) \text{ and } N- = (N_1, N_2, N_3, \ldots\ldots, N_n)$$

$$\text{Where } P_j = \{\max_i \; U_{ij4}\} \text{ and } N_j = \{\min_i \; U_{ij1}\};$$

$$i = 1, 2, \ldots, m \text{ and } j = 1, 2, \ldots., n$$

using the ideal solutions, the distance between each alternative from P+ and N- can be calculated using the following equations:

$$d_i^+ = \sum_{j=0}^{n} d_v(u_{ij} \; ; \; P_j) \; ; \; i = 1, 2, \ldots., m$$

$$\text{And } d_i^- = \sum_{j=0}^{n} d_v(u_{ij} \; ; \; N_j) \; ; \; i = 1, 2, \ldots., m$$

Where dv (. , .) is the distance measurement between two fuzzy numbers.
Finally, the closeness coefficient is calculated to determine the ranking order of all alternatives as follows:

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \; ; i = 1, 2, \ldots., m$$

An alternative with an index CCi close to 1 denotes that the alternative is close to the FPIS (P+) and far from the FNIS (N-).
The closeness coefficient represents the distances to the fuzzy positive-ideal solution (P+) and the fuzzy negative-ideal solution (N-) simultaneously by taking the relative closeness to the fuzzy positive-ideal solution.
Thus if the alternative is equal to P+, CCi = 1 and CCi = 0 if the given alternative is N-; in other words, if an alternative Ai is closer to the FPIS (P+) and farther from FNIS (N-), approaches CCi to 1. According to the descending order of CCi, the ranking order of all alternatives can be determine and select the best option among the set of feasible alternatives.
Sometimes, situation can come out with k decision makers, the given program can deal with that case, but before some actions have to be taken as explained below:
Assume that a decision group has K decision makers, and the fuzzy rating of each decision maker DK can be represented as a positive trapezoidal fuzzy number RK.
A good aggregation method will consider the range of fuzzy rating of each decision-maker. It means that the range of aggregated fuzzy rating must include the ranges of all decision-makers' fuzzy ratings. Let the fuzzy ratings of all decision makers be trapezoidal fuzzy numbers FK = (aK, bK, cK, dK). Then the aggregated fuzzy ratings 〖(y〗_(ij)) of alternatives with respect to each criterion can be defined as F = (a, b, c, d) k= 1, 2…, K. where:

$$a = \min_i \{a_k\}; b = \frac{1}{K}\sum_{k=1}^{K} b_k \; ; \; c = \frac{1}{K}\sum_{k=1}^{K} c_k \; ; \; d = \max_i \{d_k\}$$

Thus as mentioned above, the fuzzy rating and importance weight of the kth decision maker will be:

$$F_{ijK} = (a_{ijK}, b_{ijK}, c_{ijK}, d_{ijK}); V_{jK} = (v_{jk1}, v_{jk2}, v_{jK3}, v_{jk4})$$

i= 1 to m and j= 1 to n respectively.
The aggregated fuzzy weight (W_J) of each criterion can be calculated as:

$$V_j = (v_{j1}, v_{j2}, v_{j3}, v_{j4})$$

$$v_{j1} = \min_i \{v_{jk1}\}; \; v_{j2} = \frac{1}{K}\sum_{k=1}^{K} v_{jk2} \; ;$$

$$v_{j3} = \frac{1}{K}\sum_{k=1}^{K} v_{jk3} \; ; \; v_{j4} = \max_i \{v_{jk4}\}$$

V. Application Examples

For the purpose of this application example, three options will be consider as propositions for the comparative evaluation among the set of alternatives for waste management methods with the approach described above. These options are:
- Source Separation (SS)
- Source Separation with Economical motivation (SSME),
- Create selling points (IPA)

According to the lack of information and non-availability of data, an utmost care and attention are given to choose the appropriate criteria as tools that enable the alternatives to be compared from the specific viewpoint for decision makers.
For the case study of this paper, considering the socio-environmental and technico-economic aspects of various options, the following **seven criteria** (fig. 6) listed, will compose the program.

- **The local level of pre-collection (NPC):** The lack of financial resources is expected to cause the perturbation of services offered by non-governmental organization (NGOs), leading to the low pre-collection. Indeed, from the fact that the main source of income for NGOs is the household charge. Thus, the quality of service will be mainly based on the adhesion of households and the regular payment of the service charges. Therefore, less the households are subscribers, weak will be NGOs financial positions and less they will arrive to satisfy their clients. On the other hand, the effective household demand expresses the number of households that actually subscribe to pre-collection services and are willing to pay the required fees. In addition, the low effective demand in given area will increase the risk to have poor level of pre-collection. Similarly, with regard to the accessibility of agglomerations, the access to certain areas may prevent difficulties for NGOs to meet its customers properly, that will increase the risk of having low level of pre-collection.

- **The Civism of local population and households (CMPL):** Non-application of sanctions and ignorance of nuisances caused by municipal solid waste (MSW) are assumed to increase the risk of encouraging uncivil behavior. There are also chances that an individual living in unsustainable area develops uncivil behavior in MSW management. It also seems clear that an individual whose level of education is high will tend to adopt appropriate civic behaviour
- Recourse to the uncontrolled dumping (RDS): This parameter will consider the possibility for the population to have areas to dump their wastes and nearby unmanaged deposits. For that point, it will be assuming that the lack of public bins encourage households to subscribe to one NGO of MSW pre-collection to properly eliminate their wastes.
- The necessary resources or implemented (MN-MO): This parameter will reflect the cost of investment, also the cost of operations and maintenance. Thus, the size of all the activities in given area will largely depend on this parameter.

- **Contribution to local development -economic motivation techniques (CDL-TME):** This parameter will take into account the contribution and the financial risk of the proposed alternative, by estimating the economic, social and global effects that will have the initiative in its application area and on the population leaving there. Among other potential effects, the following can be mention: the creation of new jobs, emerging businesses in the sanitation sector, opening of industrial districts, new businesses of supply chain, reinforce initiatives trying to recycle wastes as Raw material, etc.

- **Participation and/or acceptance of the project by the population (PPP-APP):** This parameter expresses the degree of acceptance of the proposed management alternative by the populations and their implication to the success of the project in the given area. For that purpose, necessary information will be share with the local population to better understand different alternatives (realization, impact, etc.) and try to get their involvement to make it successful.

- **Effect on the environment and/or contribution to climate change (EE-CCC):** This refers to the amount of carbon dioxide (CO2) emissions avoided as result of the application of the proposed alternative. It also takes other impacts into account like the visual nuisance that may be created by the development of given alternative in the specific area or any noise disturbance and odors arising from productive activity for the management chain of that alternative, the potential risk to eco-systems caused by the operations of the various levels included in the management strategies of that alternative.

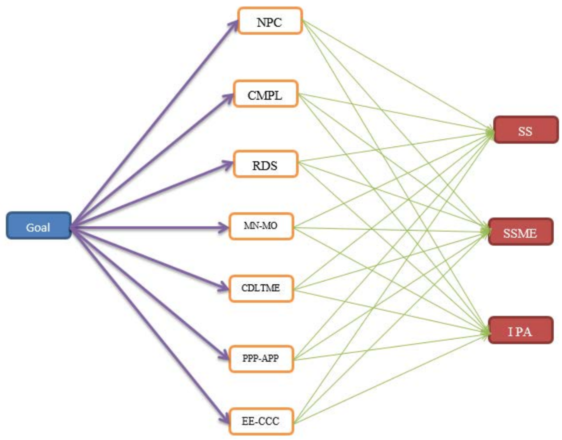

Figure 8. The hierarchical structure of this decision problem

Let consider three locations in Bamako with different level of development and education for properly highlighting the numerical simulation of the proposed models. The hierarchical structure shown in the fig.6 will be used to better identify the practical influence of different parameters on given management technique. A computing C++ program has been created for the numerical simulation and different steps of that program will be given for the first example. For the other examples, results will be summarized in the tables and followed by their interpretations.

Before proceeding with the application, it is important to provide some information on the locations to better understand some points and make sure to have accurate data. The three areas of Bamako as illustration examples of the simulation are:

- **Baconi:** located in the first municipality of the Bamako district, popular area with certain numbers of problems in road construction and access to certain areas. Also, it has a very low level of education, and the income per capita is low as well.

- **Medina-Coura:** In the center of the capital located in the second municipality of the district of Bamako, where is the only well constructed transit deposit. This area is also popular, very accessible and well-connected area. Not far from one of the popular hospital and the parliament, that will attract attention of authorities.
- **The city of Unicef**: located in the fifth Commune of the district, which is a privileged area compared to the other two that are popular areas. The population living this area is very well educated and open to improve their environment. The income per capita is considered high by taking in consideration Malian standard

The group of decision-makers based on the data provided for each location, analyzes the criteria and assign weight to each of them according to socio-economic and environmental realities in the study area. Thus after analysis, the chosen weights for various criterions are summarized in the following table:

Table 1. Criterion's weights.

Criterion	NPC	CMPL	RDS	MN-MO	CDL-TME	PPP-APP	EE-CCC
Weight	H	VH	H	VH	VH	VH	H

Taking into account the socio-economic aspects, the technical constraints and environmental realities related to the proposed management alternatives; an assigning weight for different criteria has been given by the decision makers using linguistic variables (Fig.4 and Fig. 5) for the different areas of study as follows:

Table 2. Data provided for Banconi by decision

Techniques of Management	Evaluation Criterion						
	NPC	CMPL	RDS	MN-MO	CDL-TME	PPP-APP	EE-CCC
Weight	H	VH	H	VH	VH	VH	H
Options							
SS	P	VP	MG	VG	F	MP	G
SSME	P	P	F	VG	G	F	G
I PA	MP	F	MP	G	G	G	MG

Table 3. Evaluations data given by the decision maker for Medina-Coura

Techniques of Management	Evaluation Criterion						
	NPC	CMPL	RDS	MN-MO	CDL-TME	PPP-APP	EE-CCC
Weight	H	VH	H	VH	VH	VH	H
Options							
SS	MP	P	G	VG	MG	MP	G
SSME	MP	MP	MG	VG	G	G	G
I PA	F	F	F	G	G	G	G

Table 4. Data provided by decision maker for case study of UNICEF City

Techniques of Management	Evaluation Criterion						
	NPC	CMPL	RDS	MN-MO	CDL-TME	PPP-APP	EE-CCC
Weight	H	VH	H	VH	VH	VH	H
Options							
SS	F	F	MG	VG	MG	F	G
SSME	F	MG	F	VG	G	MG	G
I PA	G	MG	MP	G	G	G	G

Then, given data of linguistic variables values for different locations and weight of criterion have been converted into fuzzy trapezoidal number. Thus, fuzzy decision matrix and the fuzzy trapezoidal number for the criterion weight can be found as shown in the table 5 for Banconi.

Table 5. Fuzzy decision matrix for Banconi

Techniques of Management	Evaluation Criterion						
	NPC	CMPL	RDS	MN-MO	CDL-TME	PPP-APP	EE-CCC
Weight	(0.7,0.8,0.8,0.9)	(0.8,0.9,1,1)	(0.7,0.8,0.8,0.9)	(0.8,0.9,1,1)	(0.8,0.9,1,1)	(0.8,0.9,1,1)	(0.7,0.8,0.8,0.9)
Options							
SS	(1,2,2,3)	(0,0,1,2)	(5,6,7,8)	(8,9,10,10)	(4,5,5,6)	(2,3,4,5)	(7,8,8,9)
SSME	(1,2,2,3)	(1,2,2,3)	(4,5,5,6)	(8,9,10,10)	(7,8,8,9)	(4,5,5,6)	(7,8,8,9)
I PA	(2,3,4,5)	(4,5,5,6)	(2,3,4,5)	(7,8,8,9)	(7,8,8,9)	(7,8,8,9)	(5,6,7,8)

Applying normalization formula to the data in table 5 will lead to Fuzzy decision matrix shown in the table 6:

Table 6. Normalized Fuzzy decision matrix for Banconi

Techniques of Management	Evaluation Criterion						
	NPC	CMPL	RDS	MN-MO	CDL-TME	PPP-APP	EE-CCC
SS	(0.1,0.2,0.2,0.3)	(0,0,0.1,0.2)	(0.5,0.6,0.7,0.8)	(0.8,0.9,1,1)	(0.4,0.5,0.5,0.6)	(0.2,0.3,0.4,0.5)	(0.7,0.8,0.8,0.9)
SSME	(0.1,0.2,0.2,0.3))	(0.1,0.2,0.2,0.3)	(0.4,0.5,0.5,0.6)	(0.8,0.9,1,1)	(0.7,0.8,0.8,0.9)	(0.4,0.5,0.5,0.6)	(0.7,0.8,0.8,0.9)
I PA	(0.2,0.3,0.4,0.5)	(0.4,0.5,0.5,0.6)	(0.2,0.3,0.4,0.5)	(0.7,0.8,0.8,0.9)	(0.7,0.8,0.8,0.9)	(0.7,0.8,0.8,0.9)	(0.5,0.6,0.7,0.8)

Using table 6 and informations given in previous steps, the weighted normalized fuzzy decision matrix is constructed and summarized in following table:

Table 7: Weighted normalized Fuzzy decision matrix for Banconi

Techniques of Management	Evaluation Criterion						
	NPC	CMPL	RDS	MN-MO	CDL-TME	PPP-APP	EE-CCC
SS	(0.07,0.16,0.16,0.27)	(0,0,0.1,0.2)	(0.35,0.48,0.56,0.72)	(0.64,0.81,1,1)	(0.32,0.45,0.5,0.6)	(0.16,0.27,0.4,0.5)	(0.49,0.64,0.64,0.81)
SSME	(0.07,0.16,0.16,0.27)	(0.08,0.18,0.2,0.3)	(0.28,0.40,0.40,0.54)	(0.64,0.81,1,1)	(0.56,0.72,0.8,0.9)	(0.32,0.45,0.5,0.6)	(0.49,0.64,0.64,0.81)
I PA	(0.14,0.24,0.32,0.45)	(0.32,0.45,0.5,0.6)	(0.14,0.24,0.32,0.45)	(0.56,0.72,0.8,0.9)	(0.56,0.72,0.8,0.9)	(0.56,0.72,0.8,0.9)	(0.35,0.48,0.56,0.72)

Using information of table 7, Fuzzy ideal solutions FPIS and FNIS are determined:

N- = [(0.07, 0.07, 0.07, 0.07), (0,0,0,0), (0.14, 0.14, 0.14, 0.14), (0.56, 0.56, 0.56, 0.56), (0.32, 0.32, 0.32, 0.32), (0.16, 0.16, 0.16, 0.16), (0.35, 0.35, 0.35, 0.35)]

P+ = [(0.45, 0.45, 0.45, 0.45), (0.6, 0.6, 0.6, 0.6), (0.72, 0.72, 0.72, 0.72), (1, 1, 1, 1), (0.9, 0.9, 0.9, 0.9), (0.9, 0.9, 0.9, 0.9), (0.81, 0.81, 0.81, 0.81)]

The ideal solutions will be used to determine the distance between each criterion form P+ and N-. Results are given in tables 8 and 9.

Table 8. Distance between each technique Ti (i=1 to 3) from P+ with respect to each criterion

Techniques of Management	Evaluation Criterion						
	NPC	CMPL	RDS	MN-MO	CDL-TME	PPP-APP	EE-CCC
SS	0.29	0.53	0.23	0.20	0.44	0.58	0.20
SSME	0.29	0.42	0.33	0.20	0.20	0.44	0.20
I PA	0.20	0.17	0.45	0.28	0.20	0.20	0.31

Table 9: Distance between each technique Ti (i=1 a 3) from N- with respect to each criterion

Techniques of Management	Evaluation Criterion						
	NPC	CMPL	RDS	MN-MO	CDL-TME	PPP-APP	EE-CCC
SS	0.12	0.11	0.41	0.34	0.18	0.22	0.32
SSME	0.12	0.21	0.28	0.34	0.44	0.32	0.32
I PA	0.25	0.48	0.19	0.22	0.44	0.60	0.22

Then the closeness coefficient is determined for each management technique as shown in the following table.

Table 10. Computation of the closeness coefficient for each technique

Techniques of Management	Calculated Parameters			
	d^-	d^*	$d^* + d^-$	CC
SS	1.7	2.47	4.17	0.4076
SSME	2.03	2.08	4.11	0.4939
I PA	2.4	1.81	4.21	**0.5701**

The Computing C++ program have been used in the other side of this study, and results are summarized in table 11 for the different locations based on the proposed techniques or alternatives.

Table 11. Results of different simulations using the computing C++ program for the different locations based on the proposed techniques or alternatives:

Techniques of Management	Calculated Parameters								
	Banconi			Medina-Coura			UNICEF City		
	d^-	d^*	CC	d^-	d^*	CC	d^-	d^*	CC
SS	1.6879411	2.4894363	0.4040672	1.7076372	2.2076005	0.4361516	1.7118781	2.1728362	0.4406703
SSME	2.0246049	2.0857356	0.4925638	2.2454261	1.6875091	0.5709288	1.9875976	1.9173509	0.5089946
I PA	2.3959127	1.8057245	0.5702331	2.2159042	1.6265831	0.5766848	2.1204349	1.7723182	0.5447134

VI. Conclusion

This paper presents studies on Bamako's waste data managing using fuzzy logic in decision making for specific chosen criterions.

In order to increase the competitive advantage of the field of waste management and decrease his effects on environment and public health, the well designed and implemented management system (chain) is an important tool for building the closeness and long-term relationships in various levels: decision makers, practitioners, engineers, researchers, etc.

With the uncertainty and impreciseness of data in waste management chain, fuzzy-set theory is adequate to deal with that situation and can be an adequate method for comparison between different options. New computing program has been created for this paper and allows easy use of fuzzy logic, which depends on many parameters and conditions. Decision makers and professionals (Engineers) can use it to predict the most useful waste management technique between the proposed ones.

An accurate use of Fuzzy TOPSIS method flexibikity can be very suitable to deal with the ratings of both quantitative as well as qualitative criteria and effectively select the best management option. The program based on Multi-criteria Decision Making Problem (MCDM) can also be useful for professionals (Engineers) making standard or simulation aided projects in waste management and sanitation fields.

The results shown in this paper are depending on decision makers choices and the weight provided to various criterion, that why for this application example for the three locations of Bamako (Banconi, Medina-Coura, Unicef City), various remarks can come out. So farther experiments are necessary to define precisely the scope of application of this program.

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