A Fuzzy-Analytical Hierarchy Model for Solid Waste Management Location in South-West Nigeria

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Abstract
Rapid urbanization and industrialization have led to the generation of considerable quantities of municipal and industrial wastes. These often result in spread of diseases, contaminations of water body and pollution of soil, thus the selection of a good landfill location is a multiple criteria problem.
This work developed fuzzy analytical hierarchical model as a decision support system. The fuzzy based hierarchical model first converted the perception into triangular fuzzy numbers and used the concept of extent value analysis to obtain the significance of each of the criterion, sub criterion and the decision alternative.
The developed model was applied to a landfill location problem of Ibadan, Oyo state. Five main criteria, sixteen sub criteria and three decision alternatives were considered via; Eleyele, Moniya and Iyana Ofa. The performances of Eleyele, Moniya, and Iyana Ofa through fuzzy based hierarchical model are 0.314, 0.324 and 0.385 respectively. The decision making technique indicates that, Iyana Ofa which has the highest performance should be selected for landfill location in Ibadan.
Fuzzy analytic hierarchic process as a decision making technique is robust and can reduce imprecision in the mapping of perceptions of decision makers into numerical evaluation, thus making fuzzy based hierarchical model accurate, stable and reliable.
Keywords: AHP, Fuzzy Logic, Solid Waste, Landfill

1. Introduction

1.1 Overview

Waste can be defined as any material that is considered to be of no further use to the owner and is discarded. Waste is generated universally and it is a direct consequence of all human activities, they are generally classified into solids, liquids and gaseous (Tampa, 2011).

Solid wastes management is the subject of this work and it represents the solid materials produced in an area that are no longer useable or considered to be of no use to human activity. The heterogeneous collection of all these solids into a facility for proper disposal is regarded as solid waste management (Contreau, 1982). Notwithstanding, waste disposal by landfill remains the way in which almost all wastes in many countries are currently disposed and remain so in many advance countries (Ball, 2004).

Lack of correct disposal procedure in solid waste management can lead to soil, water, air and aesthetic pollution, associated human health problem, as well as an increase in greenhouse gas emissions (RSA, 1998).
Landfill is a site (also known as tip, dump or rubbish) for the disposal of waste materials by burial and is the oldest form of waste treatment. It has the most common methods of organized waste disposal and remained so in many places around the world (Mackenzie and David, 1998).

Proper landfill location selection is the primary step in the disposal phase of sound waste management. If properly selected, it offers protection to the environment from irritating odors from decaying waste, reduce cost and improve quality of life. If properly implemented it would ameliorate nuisance, adverse long term effect and social rejection (South, 1998). Because wastes are in different forms and there are many stakeholders. They need to be properly managed in different parts of Nigeria.

There a lot of problems with the selection of landfill location, because there are concerns about the environment law, economic viability and cost requirements. There is a need for multi criteria decision method in landfill selection and location to evaluate the public complains and to take a proper action, so as to avoid social and economic loss. This work is an attempt to address this multi-criteria problem for a location in South-West Nigeria

1.2 Multi Criteria Decision Making

Multiple criteria decision method (MCDM) is defined as the analytical method for evaluating the advantages and disadvantages of decision alternatives based on multiple criteria paramount to the problem. Pohekar (2004) states that MCDM deals with the essential part of decision theory and analysis and seeks to find the explicitly account of more than one criterion supporting the decision process. The two classification of multiple criteria decision method are:

i. Multi Objective Decision Method (MODM).
ii. Multi Attribute Decision Method (MADM).

Multi objective decision making (MODM) is a process of optimizing the conflicting objectives in a multi objectives problem. MODM states the objectives clearly in mathematical form and subject them to a set of mathematically defined constraints. On each of the objective, upper and lower deviations are set. The purpose of MODM is to minimize these deviations (Mohsen et al., 2009). A special example of MODM is goal programming.

The MADM helps to make preference decisions. It prioritizes and evaluates all the alternatives that usually characterize multiple and conflicting attributes (Janic and Reggiani, 2002). MADM may be helpful when it is ambiguous to quantify the characterized attributes but relative importance of one criterion over the other on a particular scale can be established.

1.3 Analytic Hierarchy Process

The Analytic hierarchy process (AHP) is a widely used multiple criteria decision making tool. It is used to evaluate a multiple criteria decision support system by using a subjective approach. The AHP uses pair wise comparisons which integrates verbal judgments and enhances the precision of the results (Dorald et al., 2010).

The AHP is a theory of measurement for dealing with quantifiable and intangible criteria. These have been applied to numerous areas such as decision theory and conflict resolution (Vaidya and Kumar, 2006).

Developed by Saaty (1980), the AHP captures both objective and subjective evaluation measures, it provides a basis for checking bias in decision making. Mahmoodzadeh et al. (2007) briefly state the steps involved in AHP procedure as follows:

i. State the main goal of the decision problem clearly. This is usually in one statement.
ii. Define the whole problem into the hierarchy of the objectives. The hierarchy is structured on different levels such as: Levels 1, 2, 3, and 4 representing the goal criteria, sub criteria and alternatives respectively.
iii. Weigh each level as the function of the higher level e.g. the weight of criterion as the function of the goal is established in n by n pairwise comparisons form.

iv. Develop a judgment matrix; a priority vector to weigh the elements of the matrix is calculated by normalized Eigenvector of the matrices.

Note that the AHP is used basically for the major objective (Saaty, 1980).

Dyer and Foreman (1990) and Ulker and Sezon (2013) describe the advantages of AHP in a group setting as follows:

i. Both tangibles and intangible, individual values and share values can be included in AHP-based group decision process.
ii. The discussion in a group can be focused on objectives rather than alternatives
iii. The discussion can be structured so that every factor relevant to the discussion is considered in turn
iv. In a structured analysis, the discussion is continued until all relevant information from each individual member in a group has been considered and consensus decision those of alternative is achieved.

A larger outcome always means greater preference for a benefit or less preference for cost criteria (Saaty, 1983).

Table 1: Pair wise comparison measurement scale

Scale	The Relative Importance of the 2-Sub Element
1	Equally important
3	Moderately important with one over the another
5	Strongly important
7	Very strongly important
9	Extremely important
2, 4, 6, 8	Intermediate values

(Source: Feng and Hogyan, 2005).

1.4 Fuzzy Logic

Fuzzy logic, the well-known theory, was initiated by Zadeh (1965), it was developed to solve problems in which descriptions of activities and observations are uncertain. Wang (1997), has roughly classified fuzzy theory in five major branches as follows:

i. Fuzzy mathematics, where classical mathematical concepts are extended by replacing classical sets with a fuzzy sets

ii**.** Fuzzy logic and artificial intelligence where approximations to classical logic are introduced and expert systems are developed based on fuzzy information and fuzzy logic.

iii**.** Fuzzy systems, which include fuzzy control and fuzzy approaches in signal processing communications.

iv**.** Uncertainty and information, where different kind of uncertainties is analyzed, and

v**.** Fuzzy decision making which consider optimization or satisfaction problems with soft constraints.

Applying the fuzzy set theory for fuzzy input transformation involves two steps; firstly, the linguistics term conversion is performed to convert the verbal term to fuzzy sets. A fuzzy set is a class of object with a continuous number of membership grades (Zadeh, 1965). A membership function which assigns to each object a grade of membership scales are between [0, 1]. When the grade of membership of an object is in a set is one, this object is absolutely in that set. When the grade of membership of object is zero, the object is not absolutely in that set.

1.5 Fuzzy Analytic Hierarchy Process

The theory of fuzzy set has extended traditional mathematical decision theories, so that it can cope well with any vagueness problem which cannot be adequately treated by probability distributions. The impact and relationship among the characteristics in multi criteria problems can be described only by vague verbal descriptions. Fuzzy AHP model is used to overcome this problem (Murphy, 1995).

The traditional AHP is easy to use and because of its simplicity, but does not take into account the uncertainties that are associated from mapping of a perception into numerical number. The fuzzy logic is introduced into pair wise comparison to compensate for the deficiency of traditional AHP (Shannon, 1986).

The aim of fuzzy AHP is to provide an efficient fuzzy based hierarchical decision making technique to extract information from imprecise and vague data in the content of current application of landfill site selection. Fuzzy logic technique is employed to transfer vague and imprecise information to a precise way (Zadeh, 1986).

1.6 Previous Studies of Fuzzy AHP

Mahmoodzadeh et al. (2007) applied fuzzy AHP in the selection of a project. They stated that, the evaluation and selection of industrial project before investment decision is customarily done using technical and financial information. By integrating fuzzy with analytic hierarchy process, quantitative judgment can be qualified to make comparison more intuitionistic and reduce or eliminate assessment bias in pairwise comparison process.

Chi and Hsiao (2010) apply fuzzy AHP to enterprise resource planning system. In their work fuzzy AHP exploited the flexible practical attributes of fuzzy-AHP. Among the 32 criteria sifted out from the two aspects, product aspect and management aspect were considered key. Mohamad et al. (2009) used fuzzy AHP to rank southern Johor River. The work focused on handling vague data in the decision making process. Various aspects of the river basins were investigated to find the most efficient use of water system. Their work demonstrated fuzzy AHP is found to be able to deal with vague data using triangular numbers.

Aysegul (2012) applied fuzzy AHP as an approach for selecting global supplier in a pharmaceutical industry. Supplier selection is one of the strategic important business decision to take when making the selection, it is important which criteria are to be selected and that the best solution is identified. Vahid (2011) applied fuzzy integrated AHP in the best sequence selection in a single machine shop. The model considered all the efficiency indices; concurrently minimizes the launching and the set up cost of the equipment.

2.0 Methodology

In this section a fuzzy integrated hierarchical model to tackle landfill location problem in South-West Nigeria. The traditional AHP uses the concept of eigen-vector to obtain the priority of each of the criterion, sub criterion and the decision alternative. However extent analysis is used in the case of fuzzy AHP, to obtain the corresponding priority of the criteria, sub criteria and decision alternatives. Same approach is used in this work.

2.2 The decision criteria and sub criteria in landfill location problem

Criteria and sub criteria for landfill location are summarized below

i. Location characteristics (LCC)
   a. Size of the location (SZS)
   b. geology and hydrogeology (GHG
   c. Availability of cover material (ACM)
   d. Quality of the onsite soil (QSS)
ii. Environmental criterion (EVC)
   a. Distance to airport (DST)
   b. Distance to lake, river and underground water (DRL)
   c. Access road to the location (ARL)
iii. Social criterion (SCC)
   a. Proximity
   b. Adjacent location land use (ALU)
   c. Alternative location land use (ALS)
iv. Economic criteria
   a. Lifespan of the location (LSP)
   b. Value of the location (VLS)
   c. Distance to waste generation area (DWG)
v. Cost expected (CSE)
   a. Set up cost (SUC)
   b. Design cost (DSC)
   c. Operating cost (OPC)

Table 2: Saaty measurement Scale

Preferences	Scale	Reciprocal
Equal	1	1
Moderate	3	1/3
Strong	5	1/5
Very strong	7	1/7
Extremely strong	9	1/9
Intermediate	2,4,6,8	

Table 2 , which has a point estimate is converted into fuzzy sets of three estimates,

Table 3: Fuzzy sets measurement scale

Preferences	Triangular fuzzy scale	Reciprocal scale
Equal	(1,1,1)	(1,1,1)
Moderate	(2/3,1,3/2)	(2/3,1,3/2)
Strong	(3/2,2,5/2)	(2/5,1/2,2/3)
Very strong	(5/2,3,7/2)	(2/7,1/3,2/5)
Extremely strong	(7/2,4,9/2)	(2/9,1/4,2/7)

(Source: Min and Melachrinoudis, 1999).

2.3 Extent Analysis

The extent analysis method shows to what degree the priority of one decision criterion or alternative is bigger than all others in a fuzzy comparison matrix. Among the other fuzzy approaches, the extent analysis method has been employed in quite a number of applications due to its computational simplicity. It does consider the extent of an object to be satisfied for the goal i.e. satisfied extent. In fuzzy AHP method, the "extent" is quantified by using fuzzy numbers (Aysegul, 2012).

Before we consider the following fuzzy arithmetic operations, the terms are defined:

2.4 The model notations

The model notations are defined thus:

C_i performance of criteria i = 1, 2, 3……..n

C_{ijk} performance of criterion i compared to criterion j on a convex set k

F_i extent value of criterion i.

$\oplus$ fuzzy additive index

$\oplus$ fuzzy multiplicative index

B_{xy} estimates from the fuzzy additive multiplicative operations

V_i degree of possibility of superiority

$V_1(F_1 >= F_2)$ degree of possibility that criterion 1 is superior to 2.

W_p synthetic value

W_i weight of criterion i.

A= (a_1, a_2, a_3)

B= (b_1, b_2, b_3)

Then the following operations hold;

A $\oplus$ B = $((a_1+b_1), (a_2+b_2), (a_3+b_3))$ ………………………………………… (1)

Aθ B = $((a_1-b_1), (a_2-b_2), (a_3-b_3))$…………………………………….. (2)

A*B = $((a_1 b_1), (a_2 b_2), (a_3 b_3))$…………………………………………. (3)

$A^{-1}= (a_1, a_2, a_3)^{-1}$……………………………………………………….. (4)

Table 4: Fuzzy performance of criteria

	C_1	C_2	C_3
C_1	$(C_{111} C_{112} C_{113})$	$(C_{121} C_{122} C_{123})$	$(C_{131} C_{132} C_{133})$
C_2	$(C_{211} C_{212} C_{213})$	$(C_{212} C_{222} C_{223})$	$(C_{231} C_{232} C_{233})$
C_3	$(C_{311} C_{312} C_{313})$	$(C_{321} C_{322} C_{323})$	$(C_{331} C_{332} C_{333})$

F_1 = $\{(C_{111} \oplus C_{121} \oplus C_{131}),(C_{112} \oplus C_{122} + \oplus),(C_{113} \oplus C_{123} \oplus C_{133})\} \otimes$
$(\sum_{k=1} C_{ijk}, \sum_{k=2} C_{ijk}, \sum_{k=1} C_{ijk})^{-1}$……………………………………(5)

F_2=$\{(C_{211} \oplus C_{221} \oplus C_{231}),(C_{212} \oplus C_{222} \oplus C_{232}),(C_{213} \oplus C_{223} + C_{233})\} \otimes$
$(\sum_{k=1} C_{ijk}, \sum_{k=2} C_{ijk}, \sum_{k=1} C_{ijk})^{-1}$…………………………………… (6)

F_3= $\{(C_{311} \oplus C_{321} \oplus C_{331}),(C_{312} \oplus C_{322} \oplus C_{332}),(C_{313} \oplus C_{323} + C_{333})\} \otimes$
$(\sum_{k=1} C_{ijk}, \sum_{k=2} C_{ijk}, \sum_{k=1} C_{ijk})^{-1}$…………………………………… (7)

Then the extent values F_i, will have three estimates in each case and can be written as follows;

F_1= (B_{11},B_{12}, B_{13}),

F_2= (B_{21},B_{22}, B_{23}),

$$F_3 = (B_{31}, B_{32}, B_{33})$$

Since all the estimates are convex fuzzy numbers, all the fuzzy sets of the corresponding F_i are required to determine the overall weight. The degree of possibility of superiority is determined by using mamdanian height (Chang, 1992) as follow;

$$V_1 \ (F_1 >= F_2) = \frac{(B_{21} - B_{13}}{(B_{12} - B_{13}) = (B_{22} - B_{21})} \ \ldots\ldots\ldots\ldots\ldots\ldots \ (8)$$

$$V_1 \ (F_1 >= F_3) = \frac{(B_{31} - B_{13}}{(B_{12} - B_{13}) = (B_{32} - B_{31})} \ \ldots\ldots\ldots\ldots\ldots\ldots \ (9)$$

And for F_2

$$V_2 \ (F_2 >= F_1) = \frac{(B_{11} - B_{23}}{(B_{22} - B_{23}) = (B_{12} - B_{11})} \ \ldots\ldots\ldots\ldots\ldots\ldots \ (10)$$

$$W_p = ((\min V_i) = (\min V_1, \min \ V_2 \ \min V_3 \ )^T \ldots\ldots\ldots\ldots \ (11)$$

Normalizing equation (7),

$$W_O = (W_1, \ W_2 \ , W_3 \ ) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (12)$$

Where W is a known crisp number and this gives the priority weights of the alternatives over another.

3.0 Application and Results

3.1 Application

The fuzzy AHP model of section 2 is applied to a landfill location problem of Ibadan, Oyo state. Three independent decision alternatives are considered; Eleyele, Moniya, Iyana Ofa under which the decision criteria and sub criteria would be analyzed concurrently.

There are four levels; fig 1, depicts the hierarchy of the decision level.

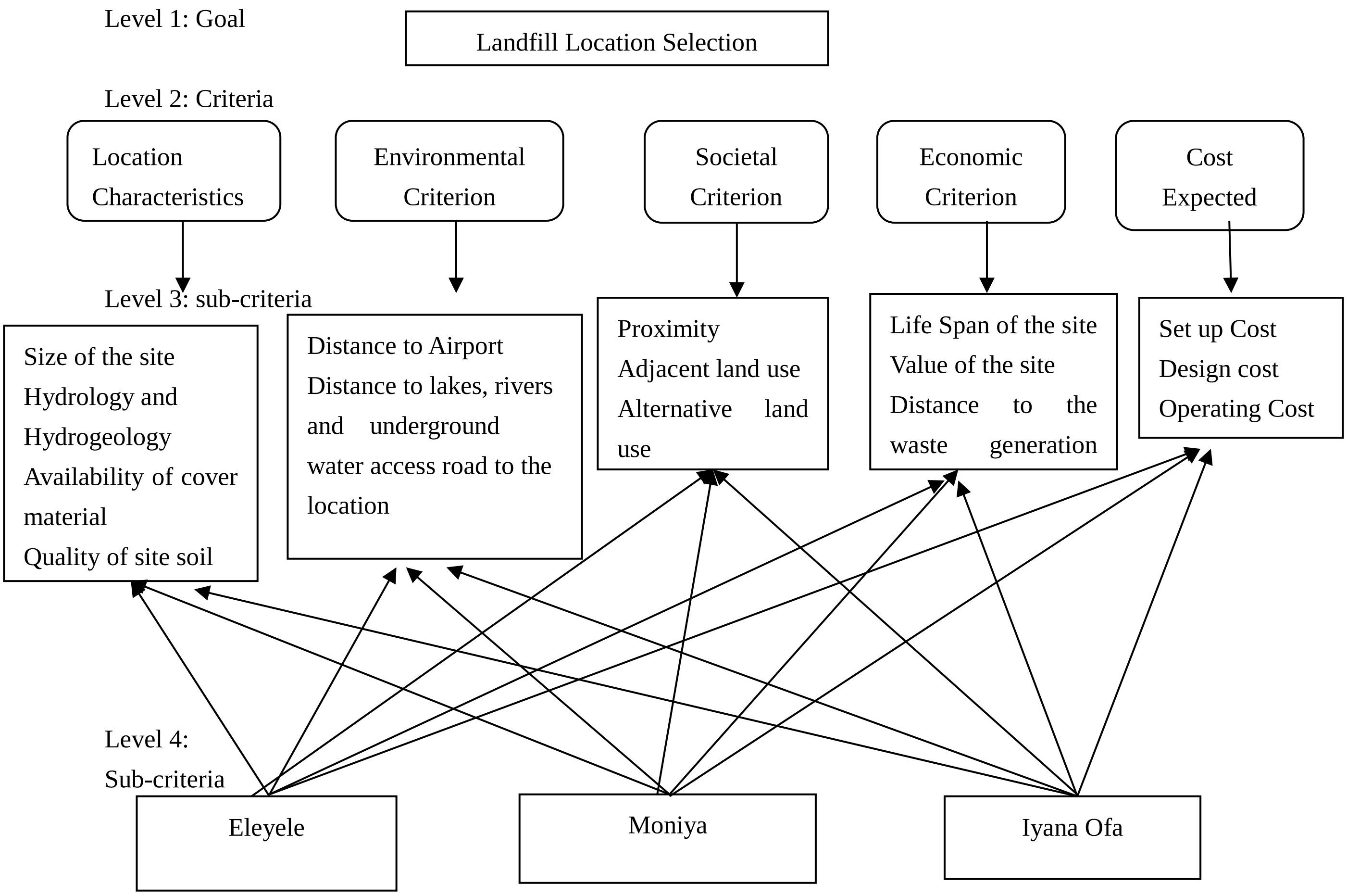

Fig 2: Hierarchical Structure of Landfill location problem in Ibadan.

The fuzzy comparison matrices of each criterion over another with respect to the overall goal, each sub criterion with respect to the main criteria and each decision alternative with respect to the sub criteria are developed on the basis of triangular fuzzy scale of linguistic preferences. Some examples of the comparisons rules used for the construction of fuzzy comparison matrices are as follows.

In terms of the overall selection of the landfill site location, if criterion LCC is strongly preferred to CSE, then it would be represented by the corresponding fuzzy number $(\frac{3}{2}, 2, \frac{5}{2})$ at the intersection of row of LCC and column of CSE. The corresponding reciprocal fuzzy number would be placed at the intersection of the row of CSE and column of LCC. Similarly, comparisons among criteria, sub criteria alternative locations will be represented by triangular fuzzy numbers.

3.2 Computational procedure

The computational procedure for calculating the priority weights of different decision variables and finally deciding the best location for landfill using the fuzzy integrated hierarchical approach can be summarized as follows:

Step 1: Fuzzy comparison matrices of criteria, sub criteria, and decision alternatives with respect to one another are developed.

Step 2: the fuzzy synthetic extent value of each criterion, sub criterion, and decision alternative with respect to one another are determined with Equations 1-7.

Step 3: the degree of possibility of superiority of each fuzzy synthetic extent value in comparison to one another is determined and the minimum degree of possibility over another is calculated

Step 4: based on the minimum degree of possibility of superiority, the weight vectors of each criterion, sub criterion, and decision alternatives are calculated.

Step 5: normalized values of the weight vectors gives the final weight of the decision criteria and sub criteria with respect to final objective and main criteria respectively.

Step 6: similarly the priority of the decision alternatives with respect to the sub criterion is decided upon.

Step 7: the priority weight combination of the sub criteria, and decision alternatives with respect to the main Criteria.

Step 8: similarly the priority weight combination of the main criteria and decision alternatives decides the priority weights of the decision alternatives with respect to the overall objective of the landfill location selection problem.

Step 9: finally the location with the highest priority weights is identified as the most suitable location for the landfill.

The numerical analysis for deciding the weight vectors of the criteria with respect to the goal was carried out and the result for the AHP is presented in Table 1.and other results for the fuzzy computations are also presented

4.Results and discussion

4.1 Results

The overall priorities of the landfill location sites are determined by adding the combined weight of the criteria to that of the decision alternatives. The final priorities weight in landfill sites location can be seen from Table 5. The highest score of the decision alternatives give an ideal about the most preferred location for landfill sitting in Ibadan.

Table 5: Summary combination of overall priority weight

	LCC =0.16	EVC= 0.26	SCC= 0.45	ECC= 0.09	CSC= 0.0312	WEIGHT
Eleyele	0.07	0.28	0.48	0.39	0.12	0.34
Moniya	0.31	0.30	0.24	0.30	0.22	0.27
Iyana Ofa	0.61	0.42	0.28	0.31	0.66	0.38

Table 6: Fuzzy comparison matrix of main criteria with respect to the overall goal

	LCC	EVC	SCC	ECC	CSE	WEIGHTS
LCC	1,1,1	2/3, 1, 3/2	2/3, 1, 3/2	2//3, 1, 3/2	5/2, 3, 7/2	0214
EVC	2/3, 1, 3/2	1,1,1	2/3, 1, 3/2	2/3, 1, 3/2	7/2, 4, 9/2	0.255
SCC	2/3, 1, 3/2	2/3,1 3/2	1,1,1	3/2, 2, 5/2	7/2, 4, 9/2	0.332
ECC	2/3, 1, 3/2	2/3, 1, 3/2	2/5,1/2, 2/3	1,1,1	3/2, 2, 5/2	0.138
CSE	2/7,1/3, 2/5	2/9,1/4, 2/7	2/5,1/2, 2/3	2/5,1/2, 2/3	1,1,1	0.062

F_1 = (5.5, 7, 9) * $(40, 32.26, 25.64)^{-1}$ F_1 = (0138, 0.248, 0.390)
F_2 = (6.5, 8, 10) * $(40, 32.26, 25.64)^{-1}$ F_2 = (0.163, 0.248, 0.390)
F_3 = (7.33, 9, 11) * $(40, 32.26, 25.64)^{-1}$ F_3 = (0.183, 0.279, 0.429)
F_4 = (4.23, 5.5, 7.17) * $(40, 32.26, 25.64)^{-1}$ F_4 = (0.106, 0.171, 0.280)
F_5 = (2.31, 2.58, 3.02) * $(40, 32.26, 25.64)^{-1}$ F_5 = (0.058, 0.078, 0.118)

The degree of possibility of superiority of F_i over F_j (i ≠ j) can be calculated by equation V ($F_i \geq F_j$). Therefore, the degree of superiority of the first criterion, i.e. location characteristics over other criterion can be calculated as follows:

$$V(F_1 \geq F_2) = \frac{(0.163-0.351)}{(0.217-0.351)-(0.248-0.163)} = 0.859$$

$$V(F_1 \geq F_3) = \frac{(0.183-0.351)}{(0.217-0.351)-(0.279-0.183)} = 0.859$$

V ($F_1 \geq F_4$) = 1.234, V ($F_1 \geq F_5$) = 1.903

For the second criterion – Environmental

V ($F_2 \geq F_1$) = 1.140, V ($F_2 \geq F_3$) = 0.870, V ($F_2 \geq F_4$) = 1.375, V ($F_2 \geq F_5$) = 2.049

For the third Criterion- Social

V ($F_3 \geq F_1$) = 1.271, V ($F_3 \geq F_2$) = 1.132, V ($F_3 \geq F_4$) = 1.506, V ($F_3 \geq F_5$) = 2.184

For the fourth criterion- Economy

V ($F_4 \geq F_1$) = 0.754, V ($F_4 \geq F_2$) = 0.628 V ($F_4 \geq F_3$) = 0.471, V ($F_4 \geq F_5$) = 1.143

For the fifth Criterion- Cost

V ($F_5 \geq F_1$) = 0.263, V ($F_5 \geq F_2$) = 0.237, V ($F_5 \geq F_3$) = 0.212, V ($F_5 \geq F_4$) = 0.287.

Using equation (11), the minimum degree of possibility of superiority of each criterion over another is obtained; the weight vectors of the criteria is given as

$$W_C = (0.70, 0.870, 1.132, 0.471, 0.212)^T$$

The normalized value of this vector decides the priority weights of criterion over another.

$$W_C = (0.214, 0.255, 0.332, 0.138, 0.062)$$

Table 7: Fuzzy comparison matrix of sub criteria with respect to LCC

LOCATION	SZS	GHG	ACM	QSS	Weight
SZS	1 , 1, 1	2/5, 1/2, 2/3	2/3, 1, 3/2	5/2, 3, 7/2	0.071
GHG	3/2, 2, 5/2	1, 1, 1	7/2, 4, 9/2	5/2, 3, 7/2	0.751
ACM	2/3, 1, 3/2	2/7, 1/3, 2/5	1, 1, 1	2/3, 1, 3/2	0.155
QSS	2/7, 1/3, 2/5	2/7, 1/3, 3/7	2/3, 1, 3/7	1, 1, 1	0.022

Table 8: Fuzzy comparison matrix of sub criteria with respect to EVC

Environmental	DTA	ARS	DRL	weight
DTA	1, 1,1	3/2, 1, 5/2	2/3, 1, 3/2	0.261
ARS	2/3, 1, 3/2	1, 1, 1	2/9, ¼, 2	0116
DRL	2/3, 1, 3/2	7/2, 4, 9/2	1,1,1	0.623

Table 9: Fuzzy comparison matrix of sub criteria with respect to the ECC

ECONOMY	LSP	VPS	DWG	WEIGHT
LSP	1, 1,1	7/2, 4, 9/2	3/2, 2, 5/2	0.927
VPS	2/9, ¼, 2/7	1, 1,1	2/3, 1, 3/2	0.036
DWG	2/5, ½, 2/3	2/3, 1, 3/2	1, 1, 1	0.038

Table 10: Fuzzy comparison matrix of sub criteria with respect to the SCC

SOCIAL	PXT	ALU	ALS	WEIGHT
PXT	1, 1,1	2/3, 1, 3/2	3/2, 2, 5/2	0.513
ALU	2/3, 1, 3/2	1, 1,1	2/3, 1, 3/2	0.305
ALS	2/5, ½, 2/3	2/3, 1, 3/2	1, 1, 1	0.200

Table 11: Fuzzy comparison matrix of sub criteria with respect to the CSC

COST	SUC	DSC	OPC	WEIGHT
SUC	1, 1,1	1, 1, 1	3/2, 2, 5/2	0.090
DSC	1, 1, 1	1, 1,1	2/3, 1, 3/2	0.263
OPC	3/2, 2, 5/2	2/3, 1, 3/2	1, 1, 1	0.647

4.2 Discussion

A total of 16 sub criteria were analyzed under the heading of the five main criteria. Preference of each sub criterion over another where first converted into the triangular fuzzy scale and then the comparison matrices were constructed. The same procedure was followed to obtain the priority weight of the sub criteria. In the calculations of the fuzzy synthetic extent value, the elements of the matrix were normalized and the same process repeated. The result of priority weight of sub criteria with respect to the main criteria were summarized on tables 7-11.

The three potential locations Eleyele, Moniya, and Iyana Ofa were also decided upon on the basis of triangular fuzzy preferences measurement scale. The fuzzy evaluation of the matrices of the preferred locations with respect to sub criteria were constructed, and weight vectors of each of the decision alternatives with respect to each sub criteria are computed. The results of the comparisons matrices of sub criteria the corresponding weight vectors of each sub criteria were as summarized in Table 12.

Also, the priority weights of the decision alternatives with respect to each criterion were calculated. This is basically the summation of the combined weight of the sub criteria and the decision alternatives. These can be seen from tables 13-17.

Similarly the overall priorities of the landfill locations were determined by adding the combined weights of the criteria and that of the decision alternatives. These final priority weights of decision alternatives are as seen table 18. The highest score of decision alternatives gives an ideal of the most prefer location decision for landfill of Ibadan.

Table 12: Fuzzy weights vector of the possible location sites with respect to sub-criteria

	ELEYELE	MONIYA	IYANA OFA
SZS	0.097	0.325	0.578
GHG	0.168	0.362	0.469
ACM	0.168	0.362	0.469
QSS	0.168	0.362	0.469
DTA	0.701	0.197	0.102
ARS	0.857	0.104	0.039
DRL	0.078	0.774	0.148
PXT	0.619	0.079	0.310
ALU	0.139	0.276	0.584
ASU	0.102	0.197	0.701
LSP	0.333	0.333	0.333
VPS	0.116	0.317	0.567
DWG	0.916	0.046	0.038
SUC	0.129	0.191	0.681
DSC	0.333	0.333	0.333
OPC	0.039	0.044	0.917

Table 13: Summary combination of the priority weights with respect to LCC

	SZS 0.071	GHG 0.753	ACM 0.155	QSS 0.022	WIGHTS
A1	0.097	0.168	0.168	0.168	0.163127
A2	0.325	0.362	0.362	0.362	0.359735
A3	0.578	0.469	0.469	0.469	0.477208

Table 14: Summary combination of the priority weights with respect to EVC

	DTA 0.261	ARD 0.116	DRL 0.623	WEIGHT
A1	0.701	0.857	0.078	0.330967
A2	0.197	0.104	0.774	0.545683
A3	0.102	0.039	0.148	0.12335

Table 15: Summary combination of the priority weights with respect to SCC

	PXT 0.523	ALU 0.305	ASU 0.2	WEIGHT
A1	0.619	0.139	0.102	0.386532
A2	0.079	0.296	0.177	0.166997
A3	0.31	0.584	0.701	0.48045

Table 16: Summary combination of the priority weights with respect to ECC

	LSP 0.927	VPL 0.036	DWG 0.038	WEIGHT
A1	0.333	0.116	0.916	0.347675
A2	0.333	0.317	0.046	0.321851
A3	0.333	0.567	0.038	0.330547

Table 17: Summary combination of the priority weights with respect to CSC

	SUC 0.09	DSC 0.263	OPC 0.647	WEIGHT
A1	0.129	0.333	0.309	0.299112
A2	0.191	0.333	0.044	0.133237
A3	0.681	0.333	0.917	0.742168

Table 18: Summary combination of the overall priority weights

	LCC 0.214	EVC 0.255	SCC 0.332	ECC 0.138	CSC 0.062	WEIGHT
A1	0.163127	0.330967	0.386532	0.347675	0.299112	0.314
A2	0.359735	0.545683	0.166997	0.321851	0.133237	0.324
A3	0.477208	0.12335	0.48045	0.330547	0.742168	0.385

4.3 Location Selection and Preference

From table 18, the priority score of Iyana Ofa (0.385) is the highest, so it recommended for selection as the most preferred location. This is because the computations have attempted and eliminated distractions from imprecise and vague information.

Observe that Eleyele was rather considered the least (0.314), as it came out worse than Moniya.

4.4 Sensitivity Analysis

A sensitivity analysis of the decision criteria and sub criteria are also carried out, to show the consequences of changes in the priority weights of the criteria and sub criteria over the final decision of the location selection. This helps the decision maker to set some alternative plans in case of any changes in the management philosophy and competitive position over time, which may affect the choice of the captive area. It has an ability to evaluate what if scenarios associated with the policy to change some preference decisions

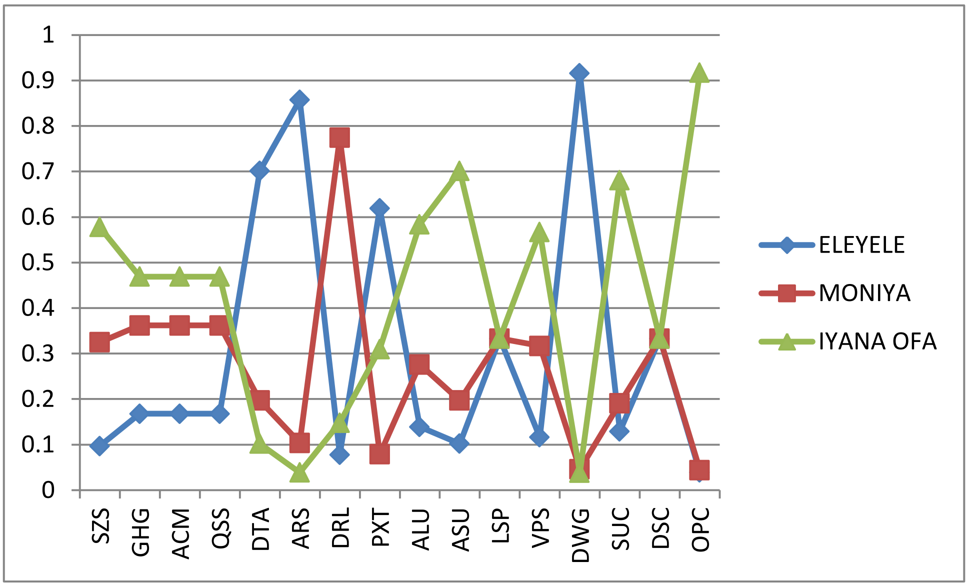

Fig 3: Sensitivity of each of the decision alternatives with respect to sub criteria

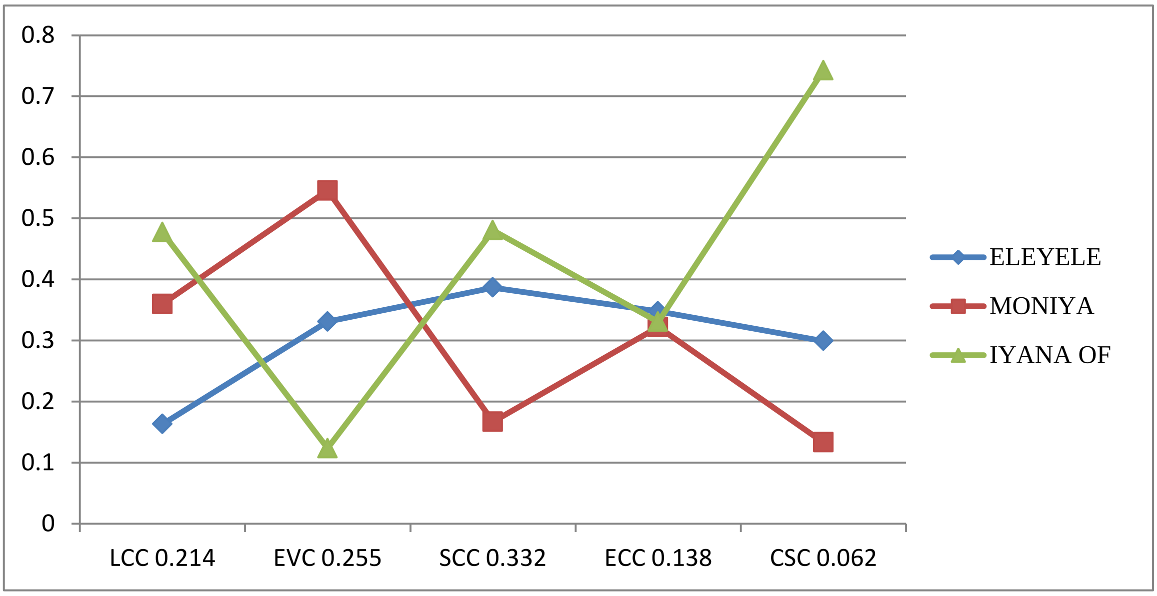

Fig 4: Sensitivity analysis of decision alternatives with respect to the main criteria

The results of the sensitivity analysis of the decision alternatives (fig. 3 and fig. 4) was also carried out with respect to sub criteria. These show that the performance of Iyana-Ofa varies in a considerable greater range compared to Moniya.

Iyana-Ofa performed very well in size of the site (location) (SZS in fig 3), geology and hydrogeology (GHG fig. 3), availability of cover materials (ACM),, quality of onsite soil (QSS), low alternative location uses, low adjacent/surrounding location uses and finally low operating cost. Whereas, Eleyele has best performance in terms of minimum distance to airport(DTA), minimum distance to waste generation area (DWG), and good access road to the site compared to both Moniya and Iyana-Ofa. Moniya has best performance in term of distance to lakes (rivers and underground water),.

Other details of the sensitivity analysis of Eleyele, Moniya and Iyana-Ofa can be seen in figures 2 and 3. Sensitivity analysis of the criteria also identified that Social acceptance as being the most important criterion for landfill location selection. This is followed by the Environmental criterion, location criterion, economy criterion, while the least criterion is the cost criterion.

5. Conclusions

The AHP is a multi-objective decision support system, it can completely analyse the given number of alternatives under the sub criteria, the sub criteria under the main criteria so as the main criteria under the main goal. Since AHP is subjective approach, which can be bias and imprecise, fuzzy logic is used to carter for the vagueness and imprecision of the subjective assessment. of the decision

Five main criteria were established, as very important to landfill location problem. These include location characteristics, social, environmental, economy and cost expected. A total of sixteen sub criteria were discussed under the five main criteria; size of the location, geology and hydrogeology, availability of cover materials, distance to airport, distance to underground water, access road to the site, proximity, adjacent location land use, alternative land use, life span of the site, value of the site, distance to waste generation area, set up cost, design cost and operating cost.

Also, the developed fuzzy integrated AHP model was applied to landfill location problem of Ibadan, Oyo state. Under the consideration of three alternatives (Eleyele, Moniya and Iyana Ofa), according to the results, Iyana-Ofa is the most suitable for landfill location in the city. However, the Fuzzy showed that values for the different preferences.

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