Reports in Mechanical Engineering
Vol. 2, No. 1, 2021, pp. 180-189
ISSN: 2683-5894, DOI: https://doi.org/10.31181/rme2001021801b

Selecting the Best Municipal Solid Waste Management Techniques in Nigeria Using Multi Criteria Decision Making Techniques

L. J. Muhammad [1], Ibrahim Badi [2], Ahmed Abba Haruna[3], I.A. Mohammed [4,5]
[1] Mathematics and Computer Science Department, Federal University of Kashere, Gombe, Nigeria, e-mail: lawan.jibril@fukashere.edu.ng
[2] Libyan Academy, Misrata, Libya, e-mail: i.badi@lam.edu.ly
[3] College of Computer Science & Engineering, University of Hafr Al Batin, Al Jamiah, Saudi Arabia, Email: ahmadydee@gmail.com
[4] Department of Computer Science, Yobe State University, Damaturu, Yobe, Nigeria,
[5] Kano University of Science and Technology, Wudil Kano, Nigeria, Email: ibrahimsallau@gmail.com

Article Info

Article history:

Received Jun 11, 2021
Revised August 17, 2021
Accepted August 28, 2021

Keywords:

MSW,
Grey theory,
EDAS,
Selection.

ABSTRACT

While developed countries use a variety of methods to convert municipal solid waste into various products such as energy, fertilizer, heat, and others, developing countries continue to struggle with municipal solid waste. Because of the various criteria to be considered, assessing these methods and determining which ones are best suited to the conditions of each country is a complicated task. The hybrid GREY-EDAS model was utilized in this study to evaluate waste treatment alternatives in Nigeria. The study employed seven distinct criteria relating to the environment, society, and cost, with the cost criterion being the most relevant. Subsequently, four waste treatment methods were evaluated: incineration, composting, sanitary landfills, and anerobic digestion. As a result, composting is proven to be the most effective. Sensitivity analysis was carried out by varying the weight of the criterion in seven distinct scenarios, and the model produced consistent findings.

Corresponding Author:

Ibrahim Badi,
Libyan Academy-Misrata, Libya, e-mail: i.badi@lam.edu.ly

1. Introduction

Municipal Solid Waste (MSW) is defined by Cointreau, (1982) as sewage emissions and non-air which created within dispose off by municipality which include commercial; refuse, household garbage, demolition and construction debris, abandoned vehicles, dead animals among other things. MSW can be defined as all sort of refuse, garbage, sludge from a waste treatment plant, water supply, air pollution contrail facility and other discarded and abounded materials such as solid, semisolid, liquid or any contained gaseous materials resulted from commercial, industrial, mining and agricultural operations (Badi and Kridish, 2020). According to World Bank, the world generates 2.01 billion MSW annually, with at least 33% of that conservatively not managed in safest environmental manner and likewise waste is generated per person per day worldwide is averagely 0.74 kilogram but ranging from 0.11 to 4.54 kilograms (World Bank, 2020). Therefore, MSW is account for 16% of the world's population, high income nations generate about 34%, or 683 million tonnes of the world's MSW (World Bank, 2020). According to Ezechi et al., (2017), municipal solid waste in Nigeria is general classified based on its origin which may include:

i. Domestic waste which comprises waste from households, restaurants, markets and other commercial areas.
ii. Industrial waste which comprises waste from private industries but excluding waste that requires special handling.
iii. Institutional waste which comprises of waste from public institutions, establishments, hospitals, schools and recreational areas.

The generation of composition of MSW is largely influenced by population, income and economic growth, climate, season and social behavior (Narayana, 2009; Badi et al., 2020). While in Nigeria the stream of MSW is generally consist of paper, plastic, metal, textile, glass among others things (Kadafa et al., 2013). The treatment of MSW is one of the global challenging issues especially to developing countries like Nigeria due to its adverse environment effects (Adekunle et al., 2011; Zamorano et al., 2009). Naturally, mankind depends solely on the environment to live and sustain their lives but MSW is one of the major three environmental problems including floods and desertification that are being threatened Nigeria (Jalil, 2010). The density of MSW in Nigeria according to Ogwueleka, (2009), is generally ranges from 280 -37 kg/m3 and its annual generation rate is 25 million tons with daily rate of 0.56 – 66 kg/capacity/day.

Municipal solid waste management has become very vital issue facing both developed and developing nations and rate of waste generation has continued to increase due to lifestyle choice, population, technological advancement and consumption which have necessitated the need to address the concern (Asase et al., 2009). Municipal solid waste management which also often called municipal solid waste treatment is defined by Ezechi et al., (2017) as the process of collecting, storing, treatment and disposal of the municipal solid waste in a way that, they can be harmless to humans, animals, plans, economy and environment in general. The management of municipal solid waste in many developed countries has evolved into material flow management which involves careful handling of raw material, job creation, reduction of green gas emission, revenue generation and environmental protection (Che et al., 2013; Odoemene and Ofodu, 2016). But however, in developing countries like Nigeria, the management of municipal solid waste is still in its infancy stage and faces many challenges. The management of municipal solid waste is generally influenced by many factors such as income level, economic development, stability and prosperity, industrialization, human attitude, urbanization and local climatic conditions (Agwu, 2012).

2. Municipal Solid Waste Treatment Technique in Nigeria

There are different types of municipal solid waste treatment techniques but the most commonly techniques used in Nigeria are open dumping, open burning, landfill, incineration, composting, recycling and anaerobic gestations (Nanda and Berruti, 2021).

2.1 Incineration

Incineration is one of the widely used technologies for municipal solid waste management in Nigeria and the technique is solely depends on the combustion of waste at high temperature. Incineration is the most cost-effective technique for waste management in Nigeria which is seldom applied in various hospitals where medical wastes are incinerated at minimal scale. The technique has the following capabilities which include:

i. It uses to reduce the organic matter content of the waste
ii. It uses to destroy contaminants and organic pathogens of the waste
iii. It uses to reduce the volume of the waste
iv. It uses for preservation of raw materials and resources

It should be noted that, incineration as one of the technologies used for municipal solid waste management in Nigeria does not eliminate waste but rather reduce and transform it into a new form which requires disposal in landfills (Ogwueleka, 2009). Incineration causes aesthetic issues such as noxious gases, foul odors and gritty smoke addition with toxicity, air quality deterioration, potential leaching of heavy metal from fly ash and also disposal of produced ash which very are critical concerns (Zhang et al., 2004). In Nigeria where the composition of the municipal solid waste is made up of mostly organic, therefore incinerators requires the supply of excess fuel foe combustion of waste due to high moisture content of the waste (Ogwueleka, 2009). But recycling of the municipal solid waste is widely practice in developed nations rather incineration technique (Sharma, 2003).

2.2 Landfilling

Landfilling is a municipal solid waste management technology technique, where a landfill relates to an areas is designated for disposal of the municipal solid waste in a way it does not pollute the surrounding environment especially ground water (Ezechi et al., 2017). According to World Bank, the generation of MSW is anticipated to rise to 3.4 billion tones by 2050. But however, the about 70% of the waste end ups in landfill and dumpsites, (Nanda and Berruti, 2021). Some challenges of the land filing of waste in Nigeria include the following:

i. Inadequate of dumping sites for waste
ii. Contamination of ground water via leaching of leachate
iii. And strict environmental laws

Land filing of waste in Nigeria happened to be mostly in either an open lands fills or sanitary landfills which tend to cause many health and enormous environmental implications.

2.3 Composting

Composting is a microbial technical driven technique for municipal solid waste management that is used to stabilize different types of waste. The techniques is used to reduce the volume of waste by 40 – 50%, produce an end product suitable for soil amendment and it is used to metabolically used to destroy pathogens in the thermophilic phase (Muhammad et al., 2015). Composting technique is not commonly used in Nigeria as means of municipal solid waste management despite its benefits which include Reduction in greenhouse gas emission and replacement of synthetic fertilizer respectively (Seruga, 2021).

2.4 Anaerobic digestion

Anaerobic digestion is a municipal solid waste management technology technique which could be thought of as one of the most sustainable and promising process for the treatment of organic waste (Seruga, 2021). The technique breaks down organic materials in the absence of oxygen. The entire process of anaerobic digestion produces biogas which consists of methane and carbon-dioxide and digestate which is rich with come macro-nutrients for needed for the growth of plant (Okoro-Shekwaga and Horan, 2015). Though, the technique is also considered as most friendly technique or method for municipal solid waste management but however, it is not commonly used in Nigeria as municipal solid waste management technique (Okoro-Shekwaga and Horan, 2015).

3. Methodology

Selecting the best technology for Municipal Solid Waste Treatment is a complex decision, because there are many criteria that influence this decision. Multi criteria decision making approaches are appropriate in such a case. The use of these approaches has increased significantly over recent years in many applications (Radović et al., 2018; Pamučar et al., 2018). The Grey systems theory, introduced by Deng in the early 1980s (Liu et al., 2011), is a methodology that focuses on solving problems involving incomplete information or small samples. The technique works on uncertain systems with partially known information by generating, mining, and extracting useful information from available data. Grey theory considers that although the objective system appears complex, with a small amount of data, it always has some internal laws governing the existence of the system and its operation. A grey number is a kind of figure that we only know the range of values, and do not know an exact value. This number can be an interval or a general number set to represent the degree of uncertainty of information. Recently, grey theory used for variety of applications. It uses a Black-Grey-White colour to describe complex systems, the concepts of a grey system can be illustrated as in Figure 1. Concept of Grey System (Abdulshahed et al., 2017)

1. Grey number, which is used to describe uncertain information, is the basic element of grey systems theory. The relationship between grey number and grey systems theory is analogous with the relationship between fuzzy number and fuzzy mathematics. A grey number is a kind of figure that we only know the range of values, and do not know an exact value. This number can be an interval or a general number set to represent the degree of uncertainty of information (Badi and Pamucar, 2020).

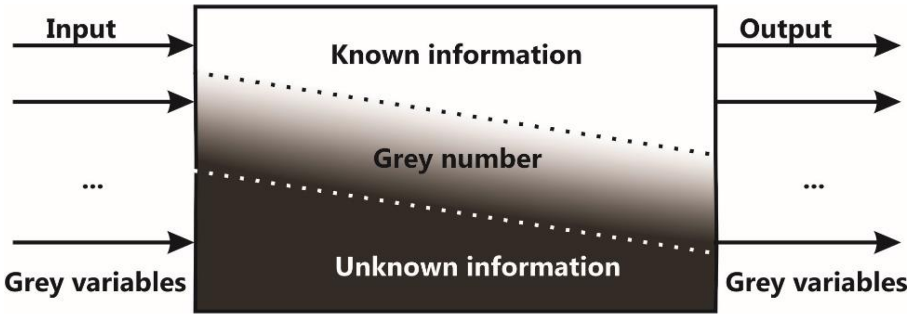

Figure 1. Concept of Grey System (Abdulshahed et al., 2017)

This study uses a hybrid grey-EDAS approach to represent decision makers' comparison evaluations as well as an extent research strategy to determine the final priority of the decision criteria in order to select the best municipal waste treatment method. The aim of this study was to offer a systematic decision-making approach for choosing the most appropriate strategy for municipal solid waste management. To simplify comparisons of the main criteria and alternatives, Macros in MS Excel were created to determine the priority weights of alternatives depending on the questionnaire forms utilized. Evaluation based on Distance from Average Solution (EDAS) method is developed by Keshavarz et al., (2015). The method is widely used in different applications of multi criteria decision making problems.

3.1 Proposed approach

The Grey-EDAS model consists of the following steps:

Step 1: Selecting the set of the most important attributes, describing the alternatives.

Step 2. Determine the attribute weights: Attribute weight W_j can be calculated as follows:

$$\otimes W_j = \frac{1}{K}\left[\otimes W_j^1 + \otimes W_j^2 + \cdots + \otimes W_j^K\right] \tag{1}$$

$$\otimes W_j^K = \left[\underline{W}_j^K, \underline{W}_j^K\right] \tag{2}$$

Step 3. Alternatives evaluated by the decision makers: decision makers use linguistic or verbal variables when evaluating alternatives according to various criteria.

$\otimes G_{ij}^K, (i = 1,2,\dots,m; j = 1,2,\dots,n)$is the attribute value given by the kth decision maker to any attribute value of the alternative. In grey system this value is shown as, $\otimes G_{ij}^K = \left[\underline{G}_{ij}^K, \overline{G}_{ij}^K\right]$ and computed as:

$$\otimes G_j = \frac{1}{K}\left[\otimes G_j^1 + \otimes G_j^2 + \cdots + \otimes G_j^K\right]$$

Step 4. The construction of Grey Decision Matrix:

$$G = \begin{bmatrix} \otimes G_{11} & \otimes G_{12} & \cdots & \cdots & \otimes G_{1n} \\ \otimes G_{21} & \otimes G_{22} & \cdots & \cdots & \otimes G_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \\ \otimes G_{m1} & \otimes G_{m2} & \cdots & \cdots & \otimes G_{mn} \end{bmatrix} \tag{3}$$

Step 5. The normalization of Decision Matrix:

$$D^* = \begin{bmatrix} \otimes G_{11}^* & \otimes G_{12}^* & \cdots & \cdots & \otimes G_{1n}^* \\ \otimes G_{21}^* & \otimes G_{22}^* & \cdots & \cdots & \otimes G_{2n}^* \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \\ \otimes G_{m1}^* & \otimes G_{m2}^* & \cdots & \cdots & \otimes G_{mn}^* \end{bmatrix} \tag{4}$$

For a benefit attribute $\otimes G_{ij}^*$ is expressed as

$\otimes G_{ij}^* = \left[\frac{G_{ij}}{G_j^{max}}, \frac{\overline{G}_{ij}}{G_j^{max}}\right]$where$G_j^{max} = max_{1<i<m}\{\overline{G}_{ij}\}$ and for a cost attribute $\otimes G_{ij}^*$ is expressed as

$\otimes G_{ij}^* = \left[\frac{G_j^{min}}{\overline{G}_{ij}}, \frac{G_j^{min}}{\underline{G}_{ij}}\right]$where $G_j^{min} = min_{1<i<m}\{\underline{G}_{ij}\}$.

Step 6. Weighted Normalized Grey Decision Matrix normalized D^* matrix is weighted by the

$$\otimes V_{ij} = \otimes G_{ij}^{*} X \otimes W_j$$

Process which establishes the weighted normalised grey decision matrix D_W^*.

$$D_W^* = \begin{bmatrix} \otimes V_{11} & \otimes V_{12} & \cdots & \cdots & \otimes V_{1n} \\ \otimes V_{21} & \otimes V_{22} & \cdots & \cdots & \otimes V_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \\ \otimes V_{m1} & \otimes V_{m2} & \cdots & \cdots & \otimes V_{mn} \end{bmatrix} \quad (5)$$

Step 4: Calculate the positive distance from average (PDA) and the negative distance from average (NDA) matrixes according to the type of criteria (benefit and cost), shown as follows:

$$PDA = \left[PDA_{ij}\right]_{nxm} \quad (6)$$

$$NDA = \left[NDA_{ij}\right]_{nxm} \quad (7)$$

if jth criterion is beneficial,

$$PDA_{ij} = \frac{max\left(0, (x_{ij} - AV_j)\right)}{AV_j} \quad (8)$$

$$NDA_{ij} = \frac{max\left(0, (AV_j - x_{ij})\right)}{AV_j} \quad (9)$$

and if jth criterion is non-beneficial

$$PDA_{ij} = \frac{max\left(0, (AV_j - x_{ij})\right)}{AV_j} \quad (10)$$

$$NDA_{ij} = \frac{max\left(0, (x_{ij} - AV_j)\right)}{AV_j} \quad (11)$$

where PDA_{ij} and NDA_{ij} denote the positive and negative distance of ith alternative from average solution in terms of jth criterion, respectively.

Step 5: Determine the weighted sum of PDA and NDA for all alternatives, shown as follows:

$$SP_i = \sum_{j=1}^{m} w_j PDA_{ij} \quad (12)$$

$$SN_i = \sum_{j=1}^{m} w_j NDA_{ij} \quad (13)$$

where w_j is the weight of jth criterion.

Step 6: Normalize the values of SP and SN for all alternatives, shown as follows:

$$NSP_i = \frac{SP_i}{max_i(SP_i)} \quad (14)$$

$$NSN_i = 1 - \frac{SN_i}{max_i(SN_i)} \quad (15)$$

Step 7: Calculate the appraisal score (AS) for all alternatives, shown as follows:

$$AS_i = \frac{1}{2}(NSP_i + NSN_i) \quad (16)$$

where $0 \leq AS_i \leq 1$

Step 8: Rank the alternatives according to the decreasing values of appraisal score (AS). The alternative with the highest AS is the best choice among the candidate alternatives.

4. The case study

In the present research, qualitative criteria, for the municipal solid waste treatment technique selection problem, are established using questionnaire forms. Table 1 shows the seven criteria that are taken into account herein. A Macros in MS Excel were developed to make the calculations.

Table 1. Criteria used

No	Criteria	Type
C1	Air and water pollution	Cost
C2	Material recovery	Benefit
C3	Land use and requirement	Cost
C4	Acceptance	Benefit
C5	Local labour experience	Benefit
C6	Capital cost	Cost
C7	Operating and maintenance cost	Cost

To help determine the importance of each criterion for evaluating the recommended methods, four experts have been asked to participate therein. Table 2 shows a scale that may be used to describe the linguistic variables in grey numbers. Table 3 shows how methods were graded on grey scales for their performance of attributes.

Table 1. The importance of grey number for the weights of the criteria.

Importance	Abbreviation	Scale of grey number $\otimes W$
Very Low	VL	[0.0, 0.1]
Low	L	[0.1, 0.3]
Medium Low	ML	[0.3, 0.4]
Medium	M	[0.4, 0.5]
Medium High	MH	[0.5, 0.6]
High	H	[0.6, 0.8]
Very High	VH	[0.8, 1.0]

Table 2. Linguistic assessment and the associated grey values.

Performance	Abbreviation	Scale of grey number $\otimes W$
Very Poor	VP	[0.0, 1.0]
Poor	P	[1.0, 2.0]
Medium Poor	MP	[2.0, 4.0]
Fair	F	[4.0, 5.0]
Medium Good	MG	[5.0, 6.0]
Good	G	[6.0, 8.0]
Very Good	VG	[8.0, 10.]

- Table 4 shows the criteria evaluation by experts using the grey scale. Next, the attributes can be weighted using equation (2).

Table **Error! No text of specified style in document.**3. The linguistic assessment of the attributes by experts.

C_i	Expert #1	Expert #2	Expert #3	Expert #4	$\otimes W$		Whitening degree
C_1	M	VL	VL	MH	0.23	0.33	0.2750
C_2	ML	H	H	ML	0.45	0.60	0.5250
C_3	ML	M	M	H	0.43	0.55	0.4875
C_4	H	L	M	M	0.38	0.53	0.4500
C_5	VH	VH	ML	M	0.58	0.73	0.6500
C_6	M	VH	H	H	0.60	0.78	0.6875
C_7	M	VH	ML	M	0.48	0.60	0.5375

- The linguistic assessment of each techniques by experts are shown in Table Error! **No text of specified style in document.**4: Transform the linguistic variables into grey numbers according to scales of grey numbers, as shown in
- Table 2 and equation (3). By the assessment of the consequences, grey decision matrix D is calculated.

Table **Error! No text of specified style in document.**4. Experts views on suggested technique selection criteria.

C_j	Techiques	**Expert #1**	**Expert #2**	**Expert #3**	**Expert #4**	**$\otimes G_{ij}$**
C_1	Technique #1	VP	VP	P	P	[0.50 1.50]
	Technique #2	F	VP	VP	F	[2.00 3.00]
	Technique #3	P	G	F	MG	[4.00 5.25]
	Technique #4	F	F	MG	F	[4.25 5.25]
C_2	Technique #1	VP	P	F	P	[1.50 2.50]
	Technique #2	F	P	MP	F	[2.75 4.00]
	Technique #3	VP	P	G	F	[2.75 4.00]

C_j	Techiques	**Expert #1**	**Expert #2**	**Expert #3**	**Expert #4**	**$\otimes G_{ij}$**
	Technique #4	F	G	MG	F	[4.75 6.00]
C_3	Technique #1	VG	F	P	MG	[4.50 5.75]
	Technique #2	VP	F	VP	G	[2.50 3.75]
	Technique #3	G	F	MP	F	[4.00 5.50]
	Technique #4	F	F	F	F	[4.00 5.00]
C_4	Technique #1	F	P	P	F	[2.50 3.50]
	Technique #2	VP	P	MP	F	[1.75 3.00]
	Technique #3	G	P	MG	F	[4.00 5.25]
	Technique #4	VG	P	F	F	[4.25 5.50]
C_5	Technique #1	VP	VG	MG	G	[4.75 6.25]
	Technique #2	VG	VG	MP	F	[5.50 7.25]
	Technique #3	F	VG	P	P	[3.50 4.75]
	Technique #4	P	VG	P	F	[3.50 4.75]
C_6	Technique #1	F	VG	MG	F	[5.25 6.50]
	Technique #2	P	VG	P	F	[3.50 4.75]
	Technique #3	P	VG	MG	F	[4.50 5.75]
	Technique #4	VP	VG	G	F	[4.50 6.00]
C_7	Technique #1	VP	VG	F	F	[4.00 5.25]
	Technique #2	F	VG	MG	F	[5.25 6.50]
	Technique #3	F	VG	P	F	[4.25 5.50]
	Technique #4	VG	VG	MP	F	[5.50 7.25]

- The normalization of Decision Matrix "D" to make the grey elements lying between 0 and 1:

$$D* = \begin{bmatrix} [0.3333\ \ 1.0000] & [0.1667\ \ 0.2500] & [0.0952\ \ 0.1250] & [0.0952\ \ 0.1176] \\ [0.2500\ 0.4167] & [0.4583\ \ 0.6667] & [0.4583\ \ 0.6667] & [0.7917\ \ 1.0000] \\ [0.4348\ \ 0.5556] & [0.6667\ \ 1.0000] & [0.4545\ \ 0.6250] & [0.5000\ \ 0.6250] \\ [0.4545\ \ 0.6364] & [0.3182\ \ 0.5455] & [0.7273\ \ 0.9545] & [0.7727\ \ 1.0000] \\ [0.6552\ \ 0.8621] & [0.7586\ \ 1.0000] & [0.4828\ \ 0.6552] & [0.4828\ \ 0.6552] \\ [0.5385\ \ 0.6667] & [0.7368\ \ 1.0000] & [0.6087\ \ 0.7778] & [0.5833\ \ 0.7778] \\ [0.7619\ \ 1.0000] & [0.6154\ \ 0.7619] & [0.7273\ \ 0.9412] & [0.5517\ \ 0.7273] \end{bmatrix}$$

- Calculate the weights of the criteria using equation (5); by grey multiplication of weights assigned to attributes with the corresponding elements of normalized grey decision matrix.

$$D* = \begin{bmatrix} [0.0750\ \ 0.3250] & [0.0375\ \ 0.0813] & [0.0214\ \ 0.0406] & [0.0214\ \ 0.0382] \\ [0.1125\ \ 0.2500] & [0.2063\ \ 0.4000] & [0.2063\ \ 0.4000] & [0.3563\ \ 0.6000] \\ [0.1848\ \ 0.3056] & [0.2833\ \ 0.5500] & [0.1932\ \ 0.3438] & [0.2125\ \ 0.3438] \\ [0.1705\ \ 0.3341] & [0.1193\ \ 0.2864] & [0.2727\ \ 0.5011] & [0.2898\ \ 0.5250] \\ [0.3767\ \ 0.6250] & [0.4362\ \ 0.7250] & [0.2776\ \ 0.4750] & [0.2776\ \ 0.4750] \\ [0.3231\ \ 0.5167] & [0.4421\ \ 0.7750] & [0.3652\ \ 0.6028] & [0.3500\ \ 0.6028] \\ [0.3619\ \ 0.6000] & [0.2923\ \ 0.4571] & [0.3455\ \ 0.5647] & [0.2621\ \ 0.4364] \end{bmatrix}$$

Using weights of criteria that are given in Table 1, the weighted normalized performance values can be calculated. Positive and negative distances are now calculated using the equations (8-11) for different strategies:

$$PDA = \begin{bmatrix} 0.0000 & 0.2580 & 0.6127 & 0.6277 \\ 0.0000 & 0.0000 & 0.0000 & 0.5111 \\ 0.1884 & 0.0000 & 0.1113 & 0.0795 \\ 0.0000 & 0.0000 & 0.2387 & 0.3043 \\ 0.0924 & 0.2662 & 0.0000 & 0.0000 \\ 0.1555 & 0.0000 & 0.0266 & 0.0419 \\ 0.0000 & 0.0971 & 0.0000 & 0.1586 \end{bmatrix}$$

$$NDA = \begin{bmatrix} 1.4984 & 0.0000 & 0.0000 & 0.0000 \\ 0.4270 & 0.0420 & 0.0420 & 0.0000 \\ 0.0000 & 0.3792 & 0.0000 & 0.0000 \\ 0.1923 & 0.3507 & 0.0000 & 0.0000 \\ 0.0000 & 0.0000 & 0.1793 & 0.1793 \\ 0.0000 & 0.2240 & 0.0000 & 0.0000 \\ 0.1590 & 0.0000 & 0.0966 & 0.0000 \end{bmatrix}$$

Finally, the appraisal score (AS) values for all proposed technologies are obtained using Equation 16 as follows:

$$AS_1 = \frac{1}{2}(0.354 + 0.000) = 0.177$$
$$AS_2 = \frac{1}{2}(0.405 + 0.358) = 0.382$$
$$AS_3 = \frac{1}{2}(0.477 + 0.764) = 0.621$$
$$AS_4 = \frac{1}{2}(1.000 + 0.856) = 0.928$$

By arranging the AS values obtained in descending order, the ranking of the proposed techniques can be obtained as follows: T4>T3>T2>T1.

The effect of altering the weights of different criteria on the ranking of the suggested techiques will be investigated in this stage after the best method has been established. The adjustment will be done for each criterion individually, by altering the weight of a specific criterion and providing equal weight to the other criteria. The sensitivity analysis findings are shown in Figure 2. In this figure, there are eight possibilities: the original model and seven alternative scenarios that came from varying the weights of each criterion. As can be shown, technology T4 is the best alternative in all cases, with technology T3 coming in second. Generally speaking, the outcome of the base model is largely stable and is not influenced by changes in criteria weights.

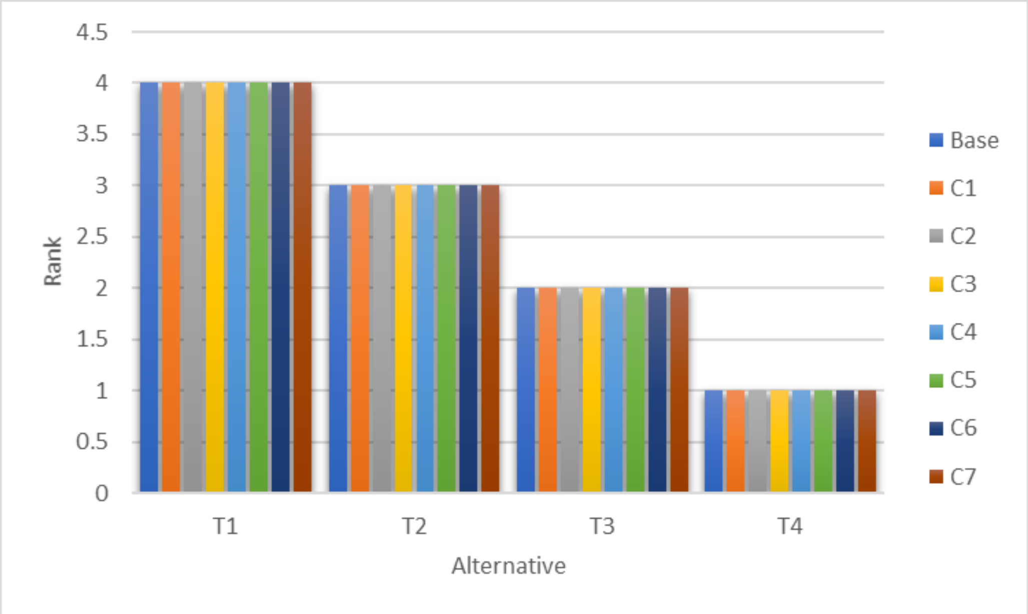

Figure 2. Sensitivity analysis

Nigeria now generates 1.3 billion tons of waste each year. This volume of municipal waste might be regarded as an opportunity to transform it into compost or energy. Besides, many developing countries, including Nigeria, confront similar difficulties. These nations' waste management systems suffer, in general, in terms of collection, transportation, and treatment. The study of selecting the best method for the treatment of municipal solid waste is critical, and it has piqued the interest of researchers all over the world. Estimates of the criteria that may be used to evaluate these techniques vary per nation, and so the findings achieved may vary accordingly. According to the results of this study, the investment cost criterion ranks first in terms of significance, with a value of 0.68, followed by the criterion for the availability of trained labor, with a value of 0.65, and lastly, the importance of environmental criterion, with a value of 0.27. Compost technology was ranked #1 in terms of preference based on the criteria utilized. Hence, this study can assist decision-makers in choosing the best technique for municipal waste treatment.

5. Conclusion

The findings of this study may be interpreted in various ways, the most important of which are the present state of the criteria employed in the study area. The capacity to offer the skilled labor necessary to operate such projects is at the forefront of these requirements, which must be seen as a problem that must be solved in terms of qualifying this manpower. Cost is also an important element, and saving money for more expensive technology might be challenging in today's world. Despite its environmental consequences, the problem of environmental awareness is still not given the attention it deserves in the study area. The environmental criterion is at the bottom of the scale. It may not come as a surprise in many third-world countries where it is difficult to dispose of waste in any way, regardless of the environmental consequences. The current form of waste management, whereby waste is frequently accumulated in streets and alleyways and burnt in open dumps, is creating more environmental damage. People's acceptance of these methods should also be carefully evaluated in order to avoid public rejection. Even when different weights were used to analyze sensitivity, the data revealed a preference for composting over alternative methods. In a country where agriculture employs 30% of the population, the byproducts of these wastes may be used therein. The incineration technique comes in second place, as it may conserve some of the energy needed.

References

Abdulshahed, A. M., Badi, I. A. & Blaow, M. M. (2017). A grey-based decision-making approach to the supplier selection problem in a steelmaking company: a case study in Libya. *Grey Systems: Theory and Application*, 7(3), 385-396.

Adekunle, I. M., Adekunle, A. A., Akintokun, A. K., Akintokun, P. O. & Arowolo, T. A. (2011). Recycling of organic wastes through composting for land applications: a Nigerian experience. *Waste management & research,* 29**,** 582-593.

Agwu, M. (2012). Issues and challenges of solid waste management practices in port-harcourt city, Nigeria-a behavioural perspective. *American Journal of Social and Management Sciences,* 3**,** 83-92.

Asase, M., Yanful, E. K., Mensah, M., Stanford, J. & Amponsah, S. (2009). Comparison of municipal solid waste management systems in Canada and Ghana: A case study of the cities of London, Ontario, and Kumasi, Ghana. *Waste management,* 29**,** 2779-2786.

Badi, I. & Kridish, M. (2020). Landfill site selection using a novel FUCOM-CODAS model: A case study in Libya. *Scientific African,* 9**,** e00537.

Badi, I. & Pamucar, D. (2020). Supplier selection for steelmaking company by using combined Grey-MARCOS methods. *Decision Making: Applications in Management and Engineering,* 3**,** 37-48.

Badi, I., Stević, Ž. & Sremac, S. (2020). An Integrated Fuzzy Model for Solid Waste Management in Libya. *Sustainability Modeling in Engineering: A Multi-Criteria Perspective.* World Scientific.

Che, Y., Yang, K., Jin, Y., Zhang, W., Shang, Z. & Tai, J. (2013). Residents' concerns and attitudes toward a municipal solid waste landfill: integrating a questionnaire survey and GIS techniques. *Environmental monitoring and assessment,* 185**,** 10001-10013.

Cointreau, S. J. (1982). Environmental management of urban solid wastes in developing countries: a project guide. International Bank for Reconstruction and Development, Washington, DC (USA ….

Ezechi, E. H., Nwabuko, C. G., Enyinnaya, O. C. & Babington, C. J. (2017). Municipal solid waste management in Aba, Nigeria: Challenges and prospects. *Environmental Engineering Research,* 22**,** 231-236.

Jalil, M. A. (2010). Sustainable development in Malaysia: A case study on household waste management. *Journal of Sustainable Development,* 3**,** 91.

Kadafa, A. A., Latifah, A. M., Abdullah, H. S. & Sulaiman, W. (2013). A comparative assessment of the municipal solid waste management services. *Life Science Journal,* 10, 823-836.

Keshavarz, M., Zavadskas, E. K., Olfat, L., & Turskis, Z. (2015). Multi-criteria inventory classification using a new method of evaluation based on distance from average solution (EDAS). Informatica, 26(3), 435-451.

Liu, S., Forrest, J. & Yang, Y. (2011). A brief introduction to grey systems theory. Proceedings of 2011 IEEE International Conference on Grey Systems and Intelligent Services, 7, 1-9.

Muhammad, L., Garba, A. & Abba, G. (2015). Security challenges for building knowledge-based economy in nigeria. *International Journal of Security and its applications,* 9**,** 119-124.

Nanda, S. & Berruti, F. (2021). Municipal solid waste management and landfilling technologies: a review. *Environmental Chemistry Letters,* 19**,** 1433-1456.

Narayana, T. (2009). Municipal solid waste management in India: From waste disposal to recovery of resources? *Waste management,* 29**,** 1163-1166.

Odoemene, U. D. & Ofodu, J. (2016). Solid wastes management in Aba Metropolis. *Int. J. Adv. Acad. Res,* 2**,** 1-7.

Ogwueleka, T. (2009). Municipal solid waste characteristics and management in Nigeria. *Journal of Environmental Health Science & Engineering,* 6**,** 173-180.

Okoro-Shekwaga, C. & Horan, N. (2015). Suitability of Anaerobic Digesters for West Africa: Nigeria as a Case Study.

Pamučar, D., Badi, I., Sanja, K. & Obradović, R. (2018). A novel approach for the selection of power-generation technology using a linguistic neutrosophic CODAS method: A case study in Libya. *Energies,* 11**,** 1-23.

Radović, D., Stević, Ž., Pamučar, D., Zavadskas, E. K., Badi, I., Antuchevičiene, J. & Turskis, Z. (2018). Measuring performance in transportation companies in developing countries: A novel rough ARAS model. *Symmetry,* 10**,** 1-36.

Seruga, P. (2021). The Municipal Solid Waste Management System with Anaerobic Digestion. *Energies,* 14**,** 1-28.

Sharma, S. (2003). Municipal solid waste management through vermicomposting employing exotic and local species of earthworms. *Bioresource technology,* 90**,** 169-173.

World Bank. (2020). Trends in solid waste management.

Zamorano, M., Molero, E., Grindlay, A., Rodríguez, M., Hurtado, A. & Calvo, F. (2009). A planning scenario for the application of geographical information systems in municipal waste collection: A case of Churriana de la Vega (Granada, Spain). *Resources, Conservation and Recycling,* 54**,** 123-133.

Zhang, S., Herbell, J.-D. & Gaye-Haake, B. (2004). Biodegradable organic matter in municipal solid waste incineration bottom ash. *Waste Management,* 24**,** 673-679.