Application of Multi-criteria Decision Analysis (MCDA) using Analytical Hierarchy Process (AHP) Technique for the Selection of a more Sustainable Waste Management Technique

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Abstract
Indiscriminate disposal of solid waste has been described as one of the most challenging environmental problems facing cities in most developing countries because of the risks to human health and the general environment. Ineffective solid waste management is a problem plaguing the environments of urban dwellings in Nigeria including Benin City. The focus of this study is to evaluate the efficiency of MCDA using AHP technique for the selection of a more sustainable solid waste management practice.The study took a comprehensive evaluation of the solid waste composition in seven major communities in Benin City; Edo State Nigeria. The communities include; Evbuotubu, Ekenwan, Ikpoba- Hill, Ogbebuya, New Benin Oko-Central and Ugbowo. Solid waste survey/ collection using the stratified random sampling approach was done on a daily bases for a period of eight (8) weeks in order to generate enough data for specific analysis. To study the presence of variability in the composition of solid waste from community to community, multivariate analysis of variance (MANOVA) was employed while the Partial Eta Square of the Pillai's trace statistics was used to determine the magnitude of variability. Multi Criteria Decision Analysis (MCDA) using Analytical Hierarchy Process (AHP) approach was employed to select the best solid waste disposal method taking into account the prevailing factors of influenced such as; economic factors, technical factors, social factors and environmental factors.Result of multivariate analysis of variance revealed that; about 98.9% of variability exists in the composition of solid waste from Ikpoba-Hill and New Benin while 82.60% variability exists in the composition of solid waste from Evbuotubu and Ekenwan. With an index of coherence (IC) of less than 10 (IC < 10), it was concluded that the comparison tables generated by evaluator A, B, C, D and E are valid. From the computation, mechanical/biological treatment (MBT) method with a total score of 74.21, 70.66, 74.30, 74.13 and 71.69 according to Evaluator A, B, C, D and E was acclaimed the best solid waste disposal option followed by recycling with a total score of 50.25, 49.61, 47.40, 48.05 and 46.52 according to Evaluator A, B, C, D and E respectively.
Keywords: Waste Characterization, Multivariate Analysis, Analytical Hierarchy Process (AHP), Multi Criteria Decision Analysis (MCDA), Sustainable Waste Management.
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1.0 Introduction

Nigerian cities and communities are faced with dangers related to inadequate solid waste handling, such as but not limited to air pollution, blockage of drainage and highways, circulation of diseases vectors, sicknesses, water contamination and poisoned ecosystems (Iro *et al.*, 2012; Remigios and Wiseman, 2012). Population surge and new materials invention has resulted to changes in the quantities and characteristics of waste generated daily (Murali *et al.*, 2014, Adeniran *et al.*, 2017). In view of environmental, human health and wildlife protection, management of solid waste in a sustainable manner is intrinsic to relevant infrastructural development (Arukwe *et al.*, 2012). The engineering approach to solid waste management include generation; collection; transportation and transsshipment; segregation, the 4Rs (recovery, reuse, recycling and reduction); treatment and disposal. Sustainable approach to solid waste management does yield dividends such as environmental sustainability, economic advancement, sustainable social and community development (Eleje *et al.*; 2017). However, these sound management approaches are not practiced in most African nations including Nigeria and her communities in urban and rural settlements ((Eleje *et al.*, 2017; Atikpo and Erameh, 2019).

Management of waste has become an issue of critical importance during last the decades mostly due to the complexity of waste streams and the steadily increasing produced volumes. Most often, the decision-making process towards efficient waste management requires the consideration of a significant number of usually conflicting criteria in order to come up with the optimal solution among alternative scenarios. Multi-criteria decision-making (MCDM) or multiple-criteria decision analysis is a sub-discipline of operations research that explicitly considers multiple criteria in decision-making environments. MCDM is concerned with theory and methodology that can treat complex problems encountered in business, engineering, and other areas of human activity (Zopounidis and Doumpos, 2002). Several MCDA methods have been proposed in recent years to help in selecting the best compromise alternatives rather than taking decisions based only on personal thoughts, views or experiences (Opricovic, 2007). Moreover, due to a rapid increase in existing technologies towards confronting waste management problems, decision makers are forced to select among a wide spectrum of available alternatives. The growing environmental consciousness of society has also raised focus from a local to regional or global.

In a research conducted by Abdulhasan et al., 2019, the authors affirm that finding locations suitable for disposal of solid waste is one of the fundamental challenges facing municipal cities and environmental stability. The focus of their study was to identify the most suitable solid waste disposal site using Geographic Information System (GIS), remote sensing, and the multi criteria decision-making (MCDM) technique. In addition, the study compares the proposed method for suitability with the traditional analytic hierarchy process (AHP) approach. The study showed that AHP, Fuzzy logic and GIS can be integrated for waste management decision issues related to site selection in order to reduce negative effects on the environment and inhabitants. Ardeshir et al., 2010 conducted a research on the selection of suitable landfill sites for the disposal of hazardous waste in Iran. In their study, the authors noted that site location of a landfill for disposing hazardous wastes is undoubtedly a main task in solid waste management. They further affirm that the existence of many conflicting criteria has changed the decision-making framework to be a difficult and complex process. Hence, they recommended a systematic two-stage procedure for proper landfill sitting using geographical information system (GIS) tool and analytical hierarchy process (AHP).

2.0 Research Methodology

2.1 Study Area Description

The study area includes selected communities in Benin City, namely; Ekenwan, Evbuotubu, Ogbebuya and Ugbowo. Others are; Ikpoba-Hill, New Benin and Oko-Central. The study area map is presented in Figure 2.1

Benin City lies between Latitude 6°20′17″ N and Longitude 5°37′32″ E with an elevation of 88 m above sea level. The city is influenced by two seasons, which are wet season (March to October) and dry season (October to March). Benin City has a borderline tropical savanna climate bordering upon a tropical monsoon climate. The weather is uncomfortably hot and humid year-round, and generally very dull, especially between July and September. It is one of the largest cities in Nigeria, located in southern part of the country, about 40 miles from the Gulf of Guinea. It is an important industrial and cultural center. Benin City is the fourth-largest city in Nigeria after Lagos, Kano and Ibadan, with a total population of 1,782,000 as of 2021 (Encyclopedia Britannica, 2020), with most of them taking their ethnic roots from local Edo culture. It is situated approximately 40 kilometers north of the Benin River and 320 kilometers by road east of Lagos. Benin City is the center of Nigeria's rubber industry, and oil production is also a significant industry (International Rubber Study Group – Nigeria, 2020). The Benin Region is underlain by sedimentary formation of the South Sedimentary Basin. The geology is generally marked by top reddish earth, composed of ferruginized or literalized clay sand.

The City has been experiencing rapid rural-urban migration and influx of displaced citizens from Northern Nigeria as a result of insurgency in recent times. Balogun and Onokerhoraye (2017) reported that population and spatial growth of Benin City are faster than the pace of infrastructure provision and that the lag between the growth of Benin City and infrastructure provision is impacting negatively on the quality of lives of the residents and threatens the sustainability of urban environment. Such a rapid growth leads to rapid increase in solid waste generation. With the exception of a few major streets swept daily within the urban agglomeration during week days, most neighborhoods in Benin City streets remain littered with solid wastes thus rendering the landscape insightful (Ogboi and Okosun, 2003).

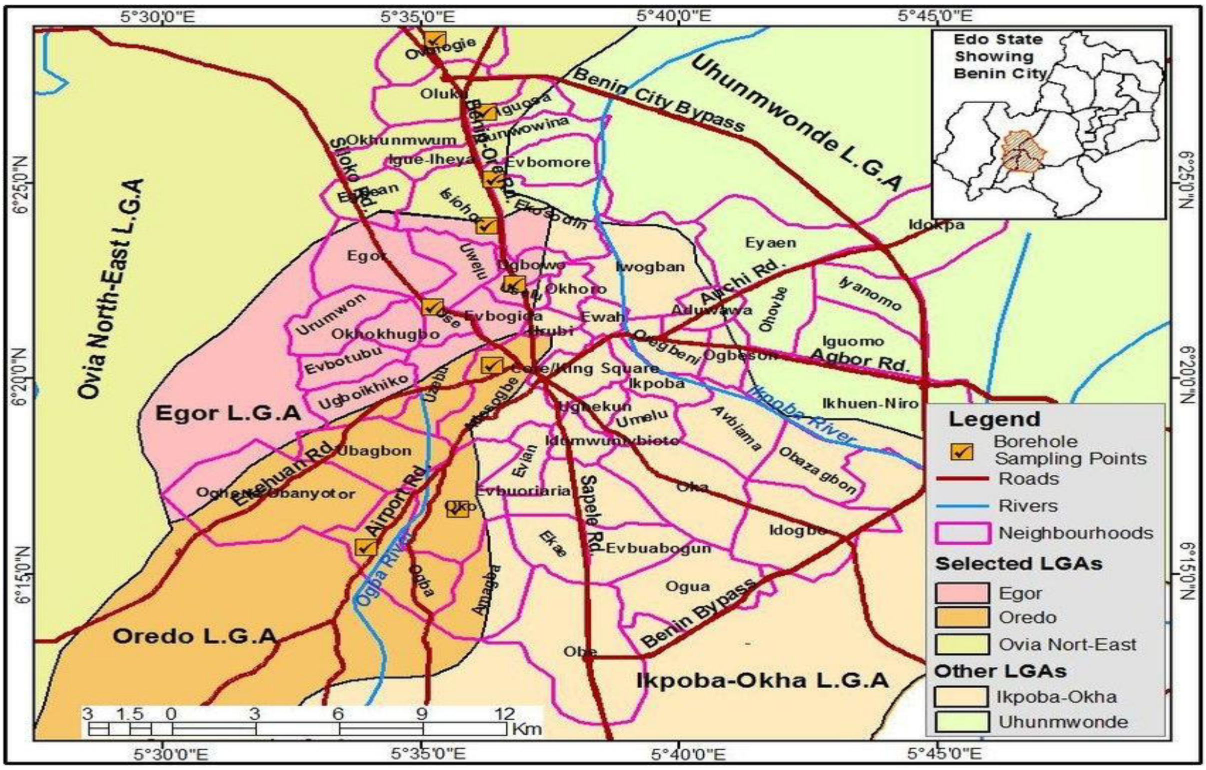

Figure 2.1: Map of study area

2.2. Materials/Equipment

2.2.1 Equipment for Data Collection

These include weighing scale, waste buckets, drums, dustbins, wheel barrows, bags, pencils, biros, notebooks, screening equipment, and a pick-up vehicle, hand gloves, face masks, hand trowels, hand forks, shovels, safety boots, helmets.

2.2.2 Household Survey

A survey questionnaire (400) per community was administered to 400 households in seven communities (Evbotubu, Oko central, New Benin, Ugbowo, Ikpoba-hill, Ogbebuya and Ekenwan) in Benin City. The questionnaire was aimed at acquiring information about residents' attitudes towards waste, socio-economic characterization, waste management behaviour (disposal and waste separation), problem faced with current management system, and how much they are willing to pay for waste management services, and whether they are aware of the possibility of converting waste to wealth.

The survey started from the first house in each street. Afterward, the alternate house was surveyed. The absence of respondent in a particular house made the next household to fall in line for survey. The door-to door questionnaire survey was conducted in one month (June, 2020), and respondents are targeted to be heads of households or their spouses. The oldest child or relative of over 16 years was targeted on the absent of the father or mother of any household. Microsoft Excel, 2016 version was applied to analyze the raw data from the questionnaire survey. The qualitative and the quantitative approach were applied for the questionnaire data analyses.

2.3 Analysis of Solid Waste Data

2.3.1 Descriptive Analysis

Descriptive statistics of solid waste data which includes; mean ($\bar{X}$), standard deviation (S), and skewness coefficient (G) were computed using the following equations

$$\text{Mean } (\bar{X}), = \frac{1}{n}\sum_{i=1}^{n} X_i \qquad (2.1)$$

$$\text{Standard Deviation (S)} = \left[\frac{1}{(n=1)}\sum\left(X_i - \bar{X}\right)^2\right]^{0.5} \qquad (2.2)$$

Coefficient of Skewness (G) = $\frac{n\sum\left(X_i - \bar{X}\right)^3}{(n-1)(n-2)S^3}$ (2.3)

Where;
X_i is observed daily rainfall data
n is the no of observations
μ is the mean and
S is the standard deviation

2.3.2 Pairwise Comparison Using Spearman's Rank Correlation

Spearman's rank correlation is a relationship measure among different parties or factors and the strength and direction of the relationship. It is a statistical measure to show the strength of a relationship between two variables. Spearman's rank correlation coefficient is used to look at the correlation of data which is ranked or put in order and how close two sets of data are linked. It is a non-parametric measure of correlation test (Alagbhari et al, 2007). The correlation is measured on a scale of -1 to +1, and may be:

i. Zero: There is no correlation between both variables
ii. Between -1 and +1: There is some correlation
iii. +1: Large values of one variable associated with large values of the other variable. It is also known as direct relationship
iv. -1: Large values of one variable associated with small values of the other variable. It is also known as inverse relationship

The Spearman's rank correlation coefficient was computed using the equation presented as follows;

$$r_S = 1 - \frac{\delta\sum d^2}{n(n^2-1)} \quad (2.4)$$

Where:
r_S is the Spearman's rank correlation coefficient
d is the different in ranking between any two parties and
n is the number of factors

2.3.3 Multivariate Analysis of Variance

2.3.3.1 Testing the suitability of MANOVA

Multivariate alliance is usually calculated through a measure known as the Mahalanobis constant. If the maximum calculated value of the Mahalanobis constant is less than the critical value, then the assumption of multivariate outliers has not been violated. Therefore, if multivariate outliers have not been violated, then we can estimate the magnitude of variability using multivariate analysis of variance (MANOVA) (Alkarkhi, 2008; Shrestha and Kazama, 2007). The schematic showing the step by step procedure of MANOVA is presented in Figure 2.2

2.4 Selection of Most Suitable Solid Waste Management Practice

The AHP is constituted by two phases:

1. The hierarchy tree definition;
2. The numerical evaluation of the tree

The hierarchy tree definition starts from the determination of the proposed goal, then criteria and sub-criteria are defined using the experience of the experts; finally, the alternatives known a priori represent the leaves of the tree as presented in Figure 2.3.

Using the information presented in Figure 2.3, AHP design was done using advance statistical software version 10.1. The AHP design which is in the form of a questionnaire was then administered to five categories of evaluators, which include; Civil Engineer (EVA), Environmental Engineer (EVB), Estate Valuer (EVC), Production Engineer (EVD) and Chemical Engineer (EVE). The evaluation phase is based on pair-wise comparison. The criteria on the same level of the hierarchy are compared to establish relative importance compared to the criterion of the father-level. This process permits to

1. Obtain values that weigh criteria, and
2. Define a ranking of the alternatives.

The evaluation is bottom-up: the decision making process starts by comparing the alternatives with the criteria of the last level; the evaluation continues up to the criteria of the first level, which are then compared to the goal. The scheme proposed by Saaty, reported in Table 2.1, was used to translate linguistic judgments into numbers.

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Table 2.1: Saaty summary table

Value	Definition	Comments
1	Equal importance	Two elements contributes equally to the objective
3	Moderate importance	Judgment slightly favour one element over another
5	Strong importance	Judgment strongly favour one element over another
7	Very strong importance	Judgment strongly favour one element over another, its dominance is demonstrated by experience
9	Extreme importance	The dominance of one element over another is demonstrated and absolute
2, 4, 6, 8	Can be used to express intermediate values	

The AHP methodology combines these data to obtain a ranking of the alternatives (usually a normalized vector). Finally, sensitivity analysis was performed using the consistency index (CI) to investigate the consequences of the variation of the weight of a criterion in order to measure the robustness of the solution and determine the criteria that have more relevance on the final result.

2.4.1 Validation of AHP Results

To validate the AHP results, the index of consistency was employed. The principal eigenvalue ($\lambda_{\max}$) is a function of the matrix divergence from consistency. In other words, a pairwise matrix is considered consistent only when $\lambda_{\max}$ equal or more than the number of the layers examined. The index of consistency was estimated using the mass balance equation of the form

$$\text{CI} = \frac{\lambda_{\max} - n}{n - 1} \tag{2.5}$$

Where; $\lambda_{\max}$ denotes the principal eigenvalue, and n represent the number of parameters. For a 3 by 3 matrix, the consistency index is less than 0.05. For a 4 by 4 matrix, it is 0.09 while for large matrices, it 0.1. If it matches, then the pairwise comparison is said to be consistent and the calculated weight of influence is said to be valid.

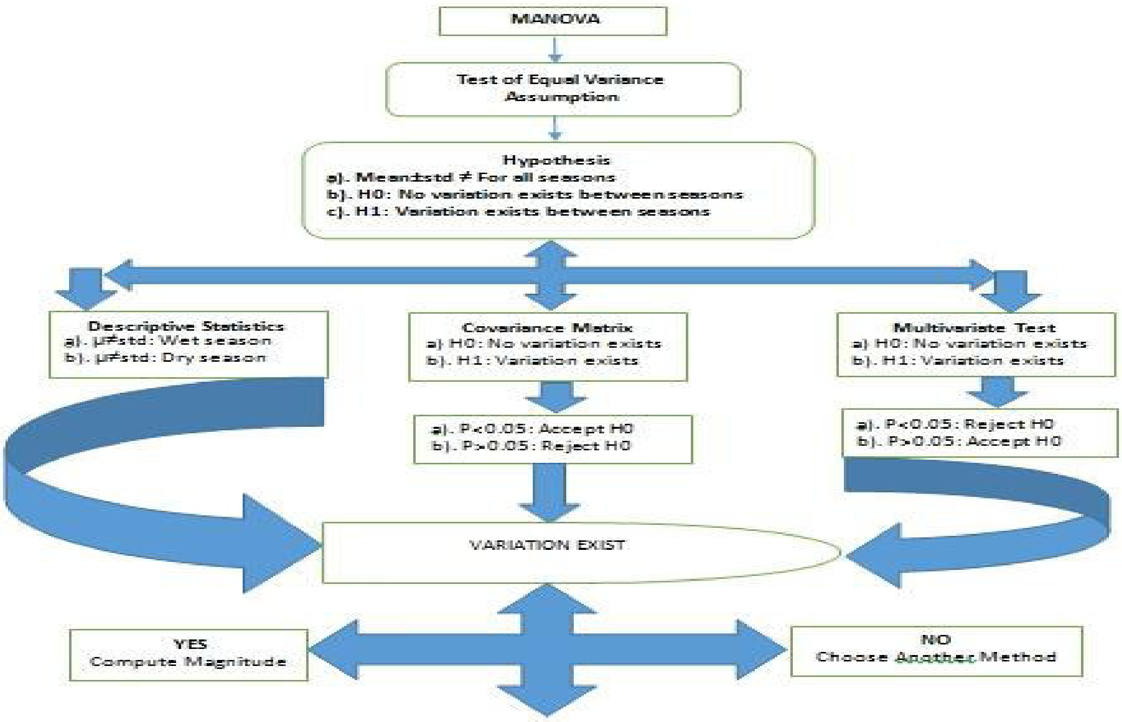

Figure 2.2: Schematic of multivariate analysis of variance

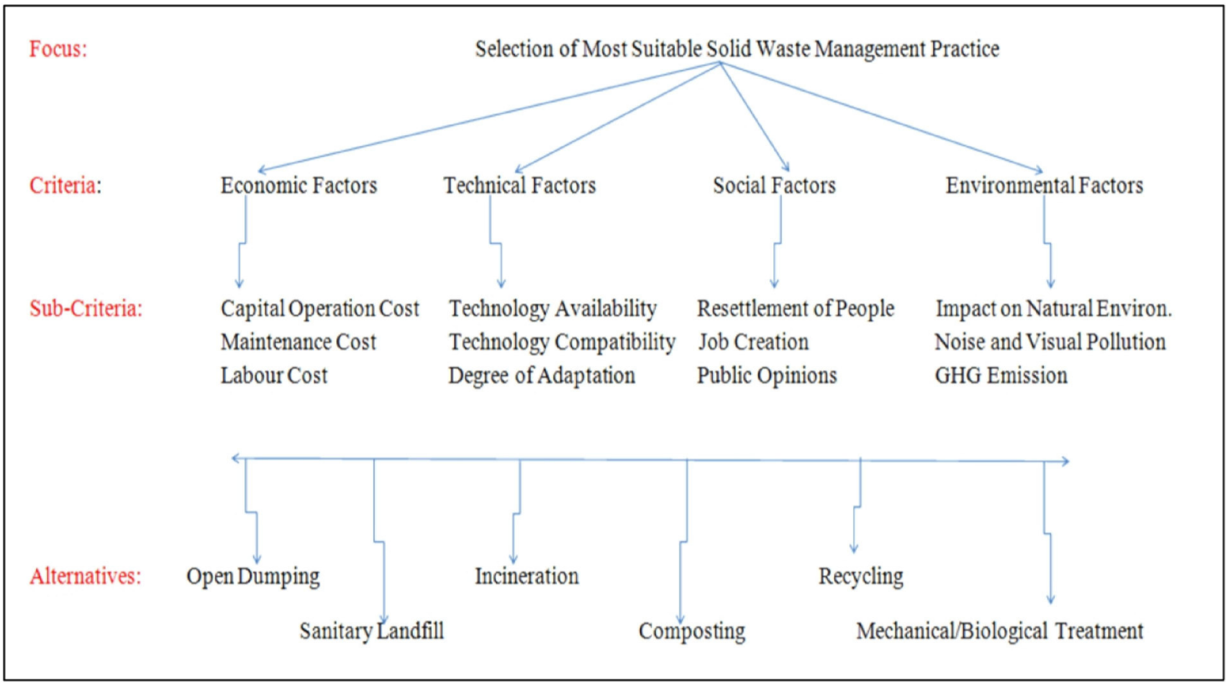

Figure 2.3: AHP Methodology

3.0 Results and Discussion

Result of solid waste characterization which was conducted in seven (7) different communities for a time frame of eight (8) weeks are presented in Tables 3.1 to 3.7

Table 3.1: Percent variation of total waste collected from Evbuotubu

S/N	Waste Components	Percentage of Waste Collected (%)							
		Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8
1	Miscellaneous Organics	18.57	16.71	24.66	37.90	42.55	42.58	46.58	42.65
2	Paper & Cardboard	15.81	16.10	17.77	11.52	12.23	11.13	11.81	16.24
3	Plastics	22.08	22.07	13.19	8.79	7.88	8.63	6.72	8.80
4	Textile	7.76	7.84	4.46	5.68	5.51	1.41	2.63	2.36
5	Metals	20.24	19.00	11.90	3.95	4.06	10.61	8.59	5.55
6	Glass	3.68	5.37	3.11	0.95	0.58	2.17	0.70	0.77
7	Tin Cans	11.85	12.91	24.91	31.22	27.19	23.47	22.97	23.63
8	Total	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0

Table 3.2: Percent variation of total waste collected from Ekenwan

S/N	Waste Components	Percentage of Waste Collected (%)							
		Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8
1	Miscellaneous Organics	61.53	64.71	65.48	62.38	62.77	80.19	61.23	49.91
2	Paper & Cardboard	10.13	7.31	3.70	6.19	4.90	2.59	7.53	11.76
3	Plastics	6.43	2.81	2.94	6.50	4.64	2.72	5.51	7.92
4	Textile	3.02	2.56	3.13	3.31	4.59	1.54	0.71	0.49
5	Metals	3.81	4.50	8.77	4.96	8.03	1.11	3.26	7.86
6	Glass	1.31	1.87	1.69	1.35	1.88	0.31	0.53	0.67
7	Tin Cans	13.77	16.24	14.29	15.32	13.19	11.54	21.22	21.39
8	Total	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0

Table 3.3: Percent variation of total waste collected from Ikpoba Hill

S/N	Waste Components	Percentage of Waste Collected (%)							
		Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8
1	Miscellaneous Organics	68.47	74.10	69.79	65.97	58.08	64.03	55.03	52.26
2	Paper & Cardboard	9.45	9.31	8.29	5.59	6.42	6.02	8.43	9.78
3	Plastics	5.05	4.39	6.55	3.99	5.88	6.19	8.90	6.89
4	Textile	3.38	1.77	2.51	5.01	4.30	2.54	1.11	1.06
5	Metals	2.52	2.19	3.48	2.88	4.30	2.10	6.90	6.28
6	Glass	2.42	1.77	1.84	5.70	3.05	1.82	1.00	0.96
7	Tin Cans	8.70	6.47	7.53	10.86	17.96	17.29	18.64	22.76
8	Total	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0

Table 3.4: Percent variation of total waste collected from New Benin

S/N	Waste Components	Percentage of Waste Collected (%)							
		Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8
1	Miscellaneous Organics	33.98	29.49	28.68	20.07	36.29	37.10	36.70	33.97
2	Paper & Cardboard	17.11	17.58	13.85	15.06	18.24	17.71	17.88	17.99
3	Plastics	18.14	13.09	12.53	17.47	14.81	14.63	14.74	12.64
4	Textile	14.47	18.28	15.52	14.53	2.52	3.93	4.03	8.07
5	Metals	13.67	16.76	18.31	22.09	18.33	13.97	15.74	21.22
6	Glass	2.26	4.71	9.40	6.59	1.00	1.96	2.34	3.29
7	Tin Cans	0.38	0.10	1.71	4.19	8.81	10.70	8.57	2.83
8	Total	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0

Table 3.5: Percent variation of total waste collected from Ogbebuya

S/N	Waste Components	Percentage of Waste Collected (%)							
		Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8
1	Miscellaneous Organics	58.93	61.13	44.07	37.31	37.46	33.22	43.53	42.02
2	Paper & Cardboard	9.07	6.10	5.45	10.98	7.07	11.94	11.45	12.12
3	Plastics	7.90	7.10	14.97	17.44	24.47	14.39	9.63	16.55
4	Textile	2.95	0.87	1.78	2.22	1.77	2.86	1.30	1.24
5	Metals	4.67	5.70	10.97	7.54	4.96	9.96	9.82	5.99
6	Glass	4.12	5.63	7.36	7.41	8.02	9.07	1.50	1.24
7	Tin Cans	12.36	13.47	15.41	17.10	16.25	18.55	22.77	20.85
8	Total	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0

Table 3.6: Percent variation of total waste collected from Oko Central

S/N	Waste Components	Percentage of Waste Collected (%)							
		Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8
1	Miscellaneous Organics	37.00	35.87	35.92	37.58	37.00	35.10	42.05	43.31
2	Paper & Cardboard	8.12	6.41	6.73	6.09	4.93	4.50	12.82	10.71
3	Plastics	6.43	12.19	13.88	6.86	12.47	14.55	7.24	7.30
4	Textile	7.95	4.51	4.15	6.72	3.38	4.25	3.01	0.80
5	Metals	5.49	6.29	9.80	10.05	9.94	7.43	8.27	8.63
6	Glass	3.04	2.86	3.47	4.03	6.27	9.06	0.58	0.60
7	Tin Cans	31.97	31.87	26.05	28.66	26.00	25.11	26.03	28.65
8	Total	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0

Table 3.7: Percent variation of total waste collected from Ugbowo

S/N	Waste Components	Percentage of Waste Collected (%)							
		Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8
1	Miscellaneous Organics	59.64	53.74	61.18	40.94	43.96	45.79	47.84	44.12
2	Paper & Cardboard	15.17	22.79	9.78	9.36	13.40	9.67	10.22	13.74
3	Plastics	7.46	9.85	6.60	9.02	7.80	7.56	7.15	9.64
4	Textile	2.56	1.75	4.85	4.14	1.98	3.25	1.72	1.07
5	Metals	4.27	2.02	4.17	3.41	6.44	3.37	2.00	6.32
6	Glass	2.11	1.84	3.73	2.29	0.75	2.07	1.88	1.22
7	Tin Cans	8.79	8.02	9.69	30.85	25.66	28.28	29.19	23.89
8	Total	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0

It was observed from the results that the solid waste around the study area composed mainly of organics, paper and cardboard, plastics, textile, metals, glass and tin cans with organics (comprising of agricultural produce and food waste constituting the main components of the waste). The graphical plots which shows the variation of solid waste composition with collection time is presented in Figures 3.1 to 3.6

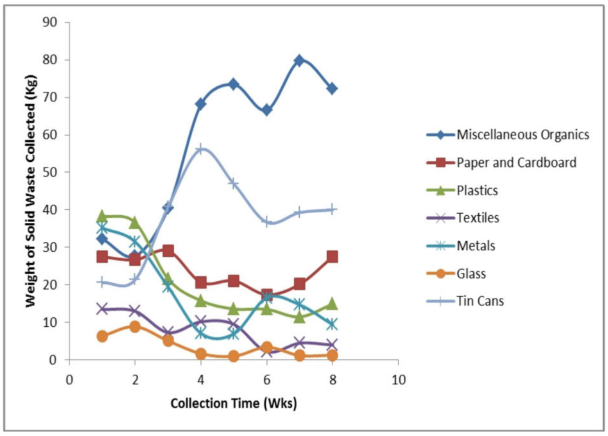

Figure 3.1: Variation of solid waste collected with with time (Ekenwan community)

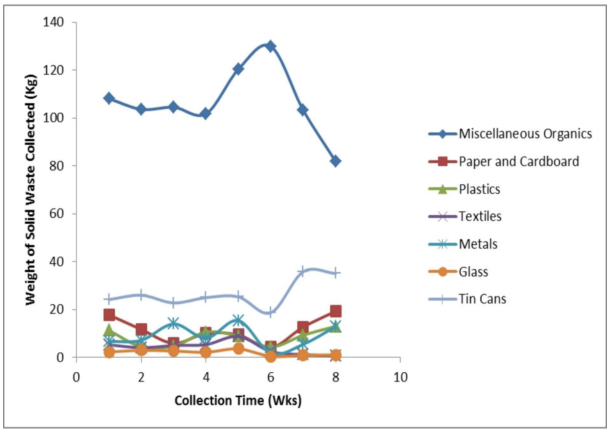

Figure 3.2: Variation of solid waste collected time (Evbuotubu community)

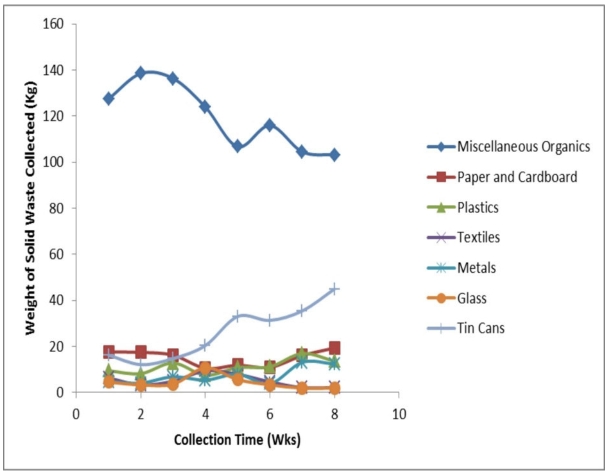

Figure 3.3: Variation of solid waste collected with time (Ikpoba Hill community)

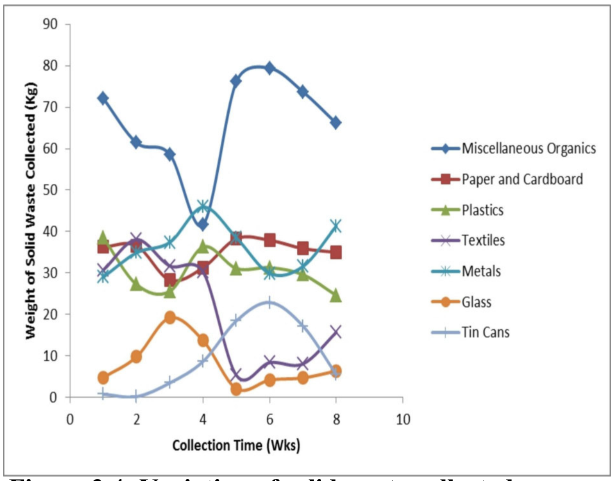

Figure 3.4: Variation of solid waste collected with time (New Benin community)

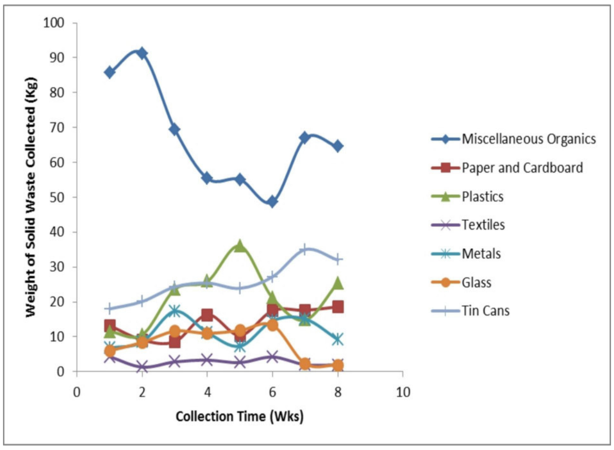

Figure 3.5: Variation of solid waste collected with time (Ogbebuya community)

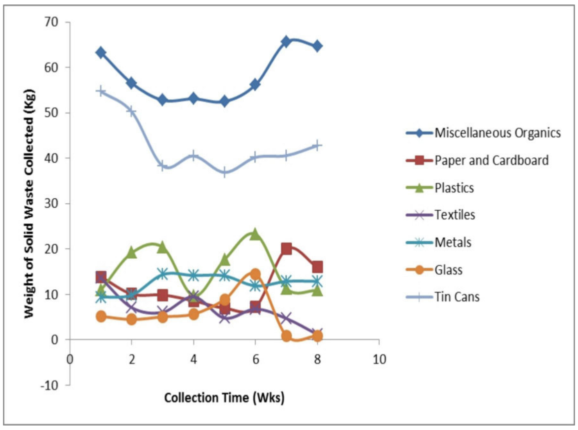

Figure 3.6: Variation of solid waste collected with time (Oko Central community)

Although the composition of solid waste collected varies from time to time, it was further confirmed from the result of Figures 3.1 to 3,6 that food waste remains the highest components of the solid waste in all the communities sampled. The reason for this is not far-fetched since the study area is mainly a residential environment which composes of different market which serves as sales point for most agricultural produce. To further ascertain the variation of solid waste composition among the different communities sampled, descriptive statistics of the waste composition was done in order to estimate the mean±std. which was employed to establish the degree of variability.

The summary statistics of waste variability on the bases of computed mean and standard deviation for all the solid waste composition collected from the different communities is presented in Table 3.8

Table 3.8: Variability of solid waste composition

Solid Waste Composition	Computed mean±std.						
	Evbuotubu	Ekenwan	Ikpoba Hill	New Benin	Ogbebuya	Oko Central	Ugbowo
Miscellaneous Organics	57.55±20.61	106.69±14.11	119.55±14.13	66.15±12.23	67.14±14.94	58.09±5.57	119.49±21.02
Paper & Cardboard	23.78±4.39	11.39±5.25	14.96±3.70	34.95±3.44	13.91±4.11	11.59±4.63	31.24±10.42
Plastics	20.74±10.77	8.34±3.39	11.30±3.09	30.53±4.91	21.11±8.55	15.44±5.29	19.54±2.98
Textile	8.03±4.22	4.14±2.62	5.08±2.65	21.02±13.00	2.80±1.08	6.73±3.66	6.34±2.94
Metals	17.63±10.73	8.95±4.70	7.28±3.65	36.06±5.87	11.25±3.96	12.46±1.93	9.64±4.16
Glass	3.63±2.92	2.04±1.10	4.35±2.85	8.11±5.78	8.29±4.44	5.71±4.40	4.75±1.94
Tin Cans	37.73±11.95	26.61±5.91	26.00±11.78	9.66±8.74	25.74±5.66	43.03±6.19	49.51±24.16

Result of Table 3.8 shows the level of variability that exists between the compositions of the solid waste from location to location. The mean±std. of plastic waste from Evbuotubu was 20.74±10.77. For plastic waste collected from Ekenwan, the mean±std was 8.34±3.39. For plastic waste collected from Ikpoba Hill, the mean±std was 11.30±3.09. For plastic waste collected from New Benin, the mean±std was 30.53±4.91. For plastic waste collected from Ogbebuya, the mean±std was 21.11±8.55. For plastic waste collected from Oko Central, the mean±std was 15.44±5.29 while for plastic waste collected from Ugbowo, the mean±std was 19.54±2.98. To determine the magnitude of variability that exist among the solid waste composition from one location to the other, multivariate analysis of variance was employed and the magnitude of variability was estimated using the Pillai’s Trace statistics. The computed magnitude of variability is presented in Tables 3.9

Table 3.9: Result of multivariate test statistics between Ikpoba Hill and New Benin

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	1.000	2.662E3[a]	7.000	8.000	.000	1.000
	Wilks' Lambda	.000	2.662E3[a]	7.000	8.000	.000	1.000
	Hotelling's Trace	2.329E3	2.662E3[a]	7.000	8.000	.000	1.000
	Roy's Largest Root	2.329E3	2.662E3[a]	7.000	8.000	.000	1.000
Group	Pillai's Trace	.989	1.028E2[a]	7.000	8.000	.000	.989
	Wilks' Lambda	.011	1.028E2[a]	7.000	8.000	.000	.989
	Hotelling's Trace	89.909	1.028E2[a]	7.000	8.000	.000	.989
	Roy's Largest Root	89.909	1.028E2[a]	7.000	8.000	.000	.989

From the result of Table 3.9, it was observed that the computed significant value (p-value) based on Roy's largest root, Wilk's Lambda, Hotelling's Trace and the Pillai's Trace was less than 0.05 ($p = 0.00$) hence, the null hypothesis that the solid waste composition are the same for the two groups (Ikpoba Hill and New Benin) was rejected and it was concluded that variability actually exist. To calculate the percent variability that is accounted for due to location, the partial Eta squared value of the Pillai's trace was employed. From the result of Table 3.9, the calculated partial Eta squared of the Pillai's trace base on group (Ikpoba Hill and New Benin) was observed to be 0.989 which indicates 98.90% variability among the dependent variables occasioned by location. Result of multivariate analysis of variance between Ogbebuya and Oko Central is presented in Table 3.10

Table 3.10: Result of multivariate test statistics between Ogbebuya and Oko Central

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.998	7.420E2[a]	7.000	8.000	.000	.998
	Wilks' Lambda	.002	7.420E2[a]	7.000	8.000	.000	.998
	Hotelling's Trace	649.267	7.420E2[a]	7.000	8.000	.000	.998
	Roy's Largest Root	649.267	7.420E2[a]	7.000	8.000	.000	.998
Group	Pillai's Trace	.861	7.071[a]	7.000	8.000	.007	.861
	Wilks' Lambda	.139	7.071[a]	7.000	8.000	.007	.861
	Hotelling's Trace	6.187	7.071[a]	7.000	8.000	.007	.861
	Roy's Largest Root	6.187	7.071[a]	7.000	8.000	.007	.861

From the result of Table 3.10, it was observed that the computed significant value (p-value) based on Roy's largest root, Wilk's Lambda, Hotelling's Trace and the Pillai's Trace was less than 0.05 ($p = 0.007$) hence, the null hypothesis that the solid waste composition are the same for the two groups (Ogbebuya and Oko Central) was rejected and it was conclude that variability actually exist. To calculate the percent variability that is accounted for due to location, the partial Eta squared value of the Pillai's trace was employed. From the result of Table 3.10, the calculated partial Eta squared of the Pillai's trace base on group (Ogbebuya and Oko Central) was observed to be 0.861 which indicates 86.10% variability among the dependent variables occasioned by location.

To select the best disposal method for the waste, multi criteria decision analysis using analytical hierarchy process was employed. To acquire data for the AHP analysis, questionnaire based approach to data acquisition was used.

The basic criteria's considered includes; Economic factors, Technical factors, Social factors and Environmental factors. The sub-criteria for Economic factor include; capital operations cost, maintenance cost and labour cost. The sub-criteria for Technical factor include; availability of technology, compatibility with existing technology. The sub-criteria for Social factor include; resettlement of people, job creation and public opinions while the sub-criteria for Environmental factors include; impact of natural environment, noise and visual pollution and greenhouse gas (GHG) emission. Six alternatives solid waste disposal techniques were selected to include; open dumping, sanitary landfill, incineration, composting, recycling and mechanical/ biological treatment. Finally, five evaluators were selected to include; EVA (Civil Engineers), EVB (Environmental Engineers/Scientist), EVC (Estate Valuers), EVD (Production Engineers) and finally, EVE (Chemical Engineers). Table 4.37 presented the input parameters employed for the AHP design. The mean priorities for the four basic selected criteria's' were calculated based on AHP and result obtained is presented in

Table 3.11

Table 3.11: Mean priorities by criterion:

Criteria	%
Economic	51.84
Technical	24.78
Social	15.38
Environment	8.00

Based on the result of Table 3.11, it was observed that Economic is the criterion that mostly impact the decision making process of all the evaluators with a percentage score of 51.84%, followed by Technical with 24.78%, then Social with 15.38% and lastly Environment with 8.00%. The pictorial representation of the calculated mean priorities by criterion is presented in Figure 3.7

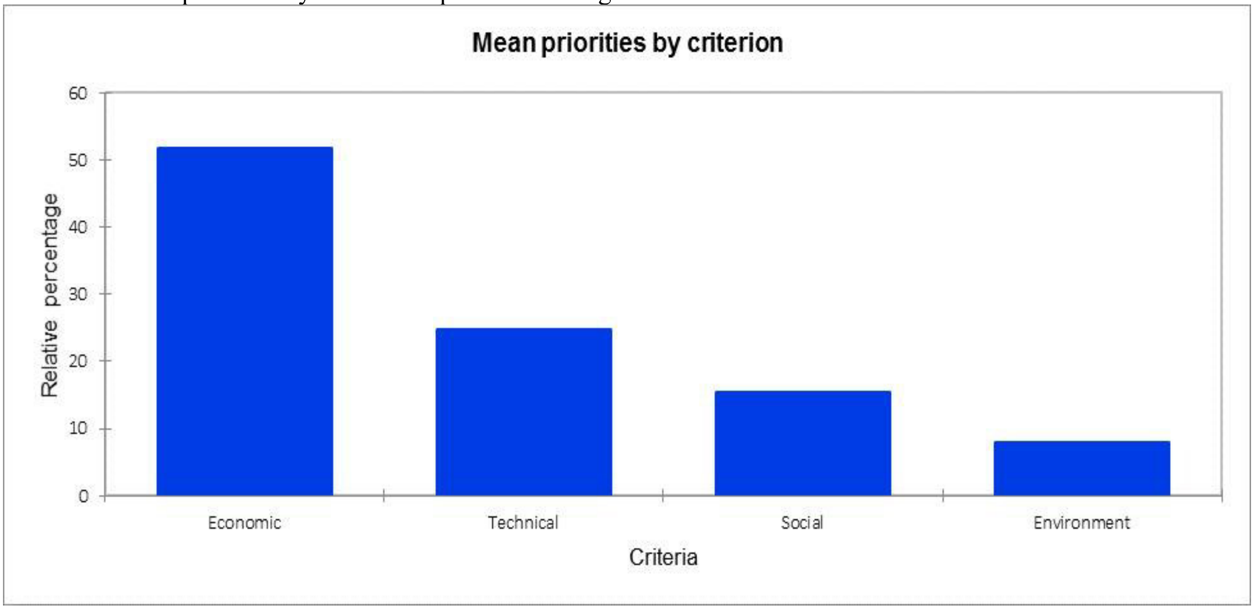

Figure 3.7: Mean priorities by criterion

To understand the sub-criterion of Economic that mostly influenced the decision making process, the mean priorities by sub-criterion of Economic was calculated and presented in Table 3.12 and Figure 3.8

Table 3.12: Mean priorities by sub-criterion of Economic:

Economic	%
Capital Operational Cost	34.22
Maintenance Cost	13.52
Labour Cost	4.10

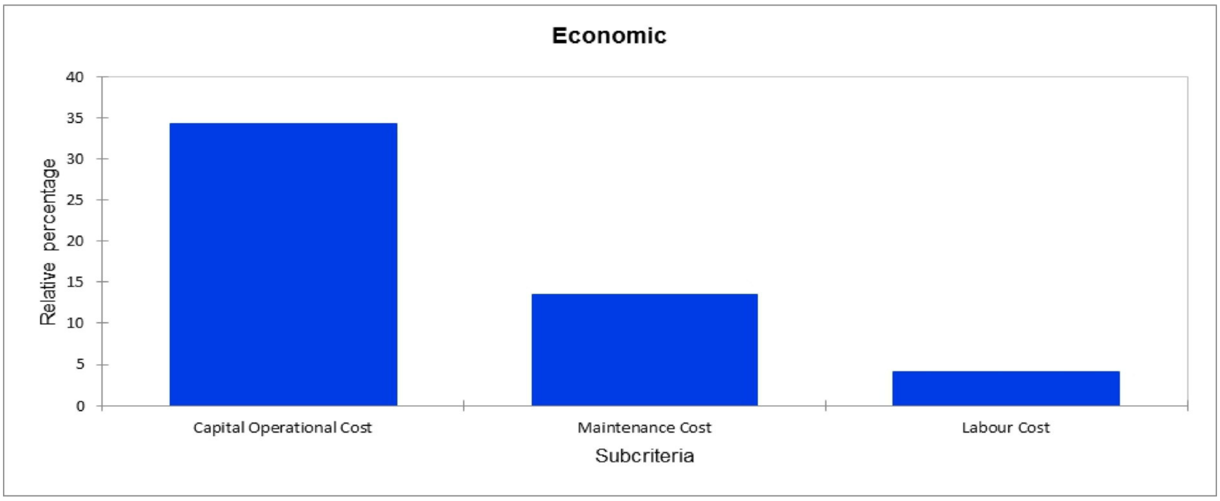

Figure 3.8: Mean priorities by sub-criterion of Engineering

From the results of Table 3.12 and Figure 3.8, it was observed that capital operational cost is the sub-criterion of Economic that mostly impact the decision making process with calculated mean priority of 34.22% followed by maintenance cost with 13.52% and lastly labour cost with 4.10%. Based on the overall perspective of the five (5) categories of evaluators, the mean priorities by alternatives was calculated for selecting the most suitable solid waste disposal method and result is presented in Table 3.13

Table 3.13: Mean priorities by alternative:

Crit./Alt.	Open Dumping	Landfill	Incineration	Composting	Recycling	MBT
Economic	2.94	3.40	8.25	5.75	12.59	18.91
Capital Operational Cost	1.95	2.25	5.32	3.83	8.38	12.50
Maintenance Cost	0.76	0.87	2.25	1.47	3.24	4.93
Labour Cost	0.23	0.27	0.69	0.46	0.97	1.48
Technical	1.40	1.72	3.98	2.86	5.98	8.83
Availability of Technology	0.81	1.03	2.41	1.72	3.53	5.01
Compatibility with Existing Technology	0.43	0.50	1.10	0.84	1.80	2.83
Degree of Adaptation	0.16	0.19	0.47	0.31	0.65	0.99
Social	0.87	1.00	2.47	1.60	3.71	5.74
Resettlement of People	0.55	0.64	1.51	1.03	2.38	3.64
Job Creation Potential	0.24	0.28	0.76	0.43	1.03	1.61
Public Opinions	0.07	0.08	0.20	0.14	0.30	0.49
Environment	0.45	0.49	1.28	0.86	1.89	3.03
Impact on National Environment	0.26	0.29	0.76	0.53	1.10	1.74
Noise and Visual Pollution	0.11	0.13	0.29	0.19	0.48	0.76
GHG Emission	0.07	0.08	0.22	0.14	0.31	0.54
Summation	**11.30**	**13.22**	**31.96**	**22.16**	**48.34**	**73.03**

To select the most suitable alternative method among the six methods, the sum of the calculated mean priorities by alternative was obtained and the alternative with the highest mean sum was adjudge the best alternative. From the computation, mechanical/biological treatment method of waste disposal had a total sum of 73.03 and was selected as the best waste disposal method followed by recycling with a total sum of 48.34, incineration with 31.96, composting with 22.16, and landfill with 13.22 and lastly, open dumping with 11.30. Hence, mechanical/biological treatment method with a total score of 73.03 was acclaimed the best waste treatment method.

Mechanical biological treatment of solid waste is emerging as the best practice in waste management sector of the last decade in developed countries. This is because it involves the processes of waste from human activities with biologically degradable constituents by the combination of mechanical and other physical procedures with biological methods. It has the advantages of improving the biodegradable contents of solid waste, reduction of methane emissions from landfill, decreasing the quantity of contaminant capacity of landfill leachates, and wastes minimization (Troschinetz and Mihelcic 2009). MBT was considered because of its potential to compete favourably in Nigeria considering the waste composition and the growth rate of the economy.

4.0 Conclusion

This study took a comprehensive evaluation of the solid waste composition in seven major communities in Benin City, Edo State Nigeria. The communities include; Evbuotubu, Ekenwan, Ikpoba- Hill, Ogbebuya, New Benin Oko-Central and Ugbowo. Solid waste survey/ collection using the stratified random sampling approach was done on a daily bases for a period of eight (8) weeks in order to generate enough data for specific analysis that are peculiar to solid waste management and sustainable development. On the overall performance of the AHP model as a decision tool for solving solid waste disposal problem, it was observed that; Economic factor is the criteria that mostly impact the decision making process of all the evaluators with a percentage score of 51.84%, followed by Technical factor with 24.78%, then Social factor with 15.38% and lastly Environmental factor with 8.00%. With an index of coherence (IC) of less than 10 (IC < 10), it was affirmed that the comparison tables generated by evaluator A, B, C, D and E are valid. From the computation, mechanical/biological treatment (MBT) method with a total score of 74.21, 70.66, 74.30, 74.13 and 71.69 according to Evaluator A, B, C, D and

E was acclaimed the best solid waste disposal option followed by recycling with a total score of 50.25, 49.61, 47.40, 48.05 and 46.52. Arising from the results of this study, it is recommended that sustainable environmental waste management should not only be considered from the economic view point but should also incorporate financial, technical and social criteria.

5.0 References

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