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RESEARCH ARTICLE

MODELING OF EXPERTS OPINIONS FOR EFFICIENT MANAGEMENT OF SOLID WASTE IN NIGERIA

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ABSTRACT

Analytical Hierarchy Process which is a multi-criteria nonlinear structure for carrying out both deductive and inductive thinking was adopted into modeling of experts opinions for the efficient management of solid waste in Nigeria. The sample area with regards to this study was the Niger Delta Region of Nigeria. Due to the qualitative nature of the study, purposive sampling technique a non-probabilistic sampling technique was employed in data collection from 150 experts within the sample area. For this, study two models (one based on the relative measurement of proposed alternative and the other based on the absolute measurement of proposed alternatives) were designed using systems approach for efficient solid waste management in Nigeria. The result obtained from the data analysis showed that the model based on the absolute measurement of proposed alternative performed better with judgment consistence ranging from 0.01 – 0.06 among the experts (respondents). Also the results obtained from this study showed that efficient solid waste management can be achieved in Nigeria with the joint efforts of the private waste management sector and government waste management agencies (57.66%). The focus to be on the increase in public awareness on the proper waste management practices (33.8%), training of waste mangers both in government and private agencies (31.5%), proper execution and implementation of waste management Acts (79.24%), giving of incentives and tax holidays to waste recyclers/ re-users (60.98%), proper solid waste disposal and treatment process/facilities (74.11%), and reduction in the rate of solid waste generation rate within the Nation (50.96%).

INTRODUCTION

The management of our environment is a major concern. The environmental problems experienced by nations around the world is as a result of poor environmental management which includes inefficient solid waste management systems (Omofonmwan and Osa-Edoh, 2008). The inefficiencies experienced by solid waste management agencies and systems is as a result of many factors which includes poor cultural practices, poor funding of the solid management sector, poor environmental legal/policy framework, poor attitude towards the environment, etc (Ibimilua and Ibimilua, 2014). Experts/researchers are of the opinion that an Integrated Solid Waste Management System or a System approach is the most effective way to management solid waste (UNEP, 2005). In its plain sense Integrated Solid Waste Management (ISWM) features the waste management hierarchy (Ashalakshmi and Arunachalam, 2010; Ramachandra (2011). Three main components are recognised by systems approach of integrated solid waste management. They include the stakeholders, the elements, and the aspects (SchÜbeler *et al,* 1996; Guerrero *et al.*, 2013; Thyberg and Tonjes, 2015).

The Stakeholders

These are the people (or organisation(s)) that are directly involved in the management of solid waste. They are grouped into service users such as the waste generators, service providers which is usually the government and the service contractors which include formal and informal private waste sectors, local and international institutions dealing with solid waste management.

The Element

This is the technical aspect of solid waste management such as waste generation, collection, storage, transportation and transfer, processing and disposal of solid waste.

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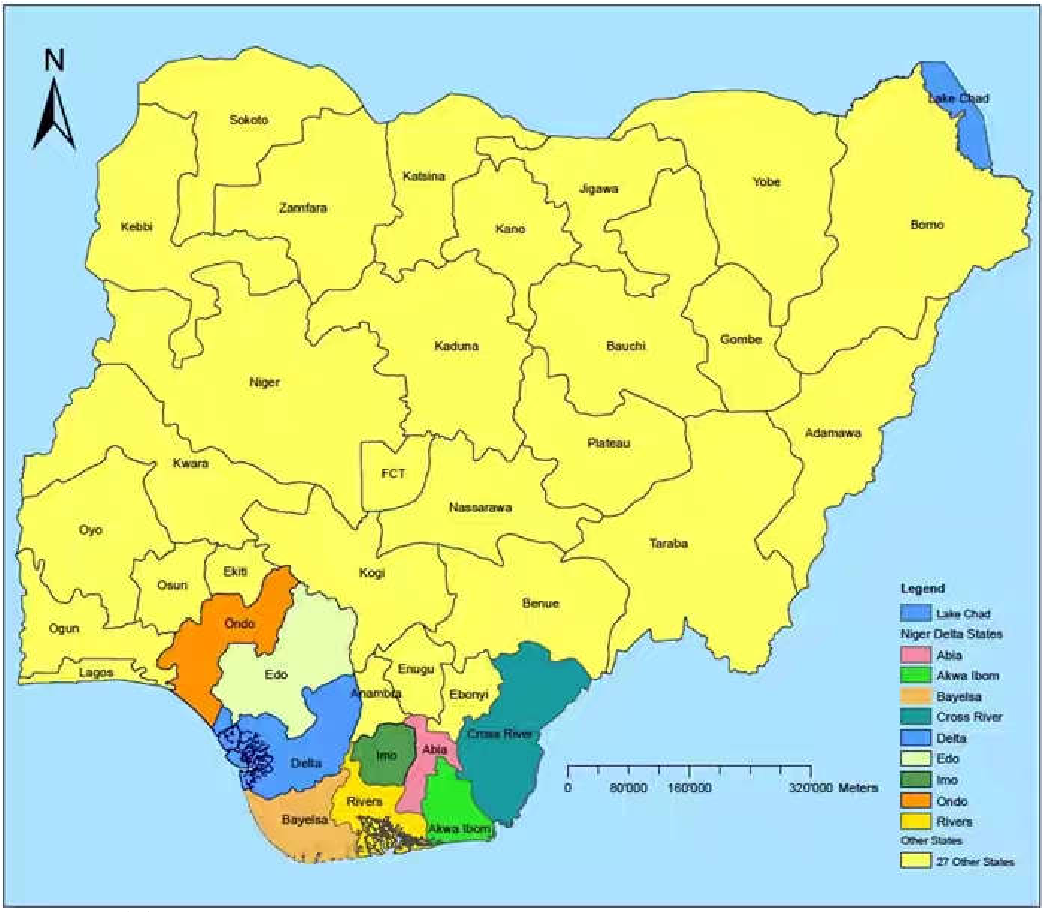
The Aspects

This is the section that tends to access and aids the efficient management of solid waste. The aspects include political, financial, legal, social and environmental requirements of solid waste management. Most solid waste management systems have effectively been managed from developed models varying in goals and methodologies since the 1960s (Marshall and Farahbakhsh, 2013). These models includes route optimization models for waste collection and disposal, waste generation rate prediction models, waste to energy conversion and prediction models, waste characterization models and decision support tools/systems models to aid decision makers in efficient solid waste management (Pires *et al.*, 2011). Modeling of Experts' opinions into the efficient management of solid waste using Analytical Hierarchy Process (AHP) takes into cognizance certain factors which influence the opinion/decision experts make on a subject matter. These influencing factors includes their level of experience, belief, knowledge exposure, Professional practices and ethics, etc. (Yongping and Guohe, 2010). Analytical Hierarchy Process is a nonlinear structure for carrying out both deductive and inductive thinking, it is a multi-criteria decision making method developed and introduced by Saaty in 1980 (Dalalah *et al*., 2010). It takes several factors into consideration simultaneously and allow for dependence and for feedback, making numerical tradeoffs to arrive at a synthesis or conclusion (Saaty, 2008). AHP has been widely applied in various fields, such as planning, selecting best alternatives, resource allocations, conflict resolution, optimization e.t.c (Vaidya and Kumar, 2006). Dalalah *et al.* (2010) used AHP to build a model for the construction industry to aid the choice of Cranes. Also, Generino *et al.* (2014) applied AHP in the spatial modeling of floodplain risk assessment in Cagayan province of northern Philippines.

MATERIALS AND METHODS

Sample Area

The sampling area with regards to this study was the Niger Delta Region of Nigeria. It comprises of about eight (9) States (Rivers, Edo, Ondo, Delta, Cross Rivers, Bayelsa, Imo, Abia and Akwa Ibom) with 185 Local Government Area (UNDP, 2006). From research, it is said to have the largest wetland in Africa among the three largest in the world (Oviasuyi and Uwadiae, 2010). The Niger Delta is host to Nigeria's huge deposits of oil and gas. Due to the geographical location of the region, the traditional occupation of the inhabitants of the Niger Delta is fishing and farming. The region of Niger Delta is characterized with environmental challenging issues such as oil pollution, environmental degradation, and destruction of aquatic lives from the activities of oil and gas exploration. Figure 1 presents a map of the sample area.



Source: Google images, 2016

Figure 1. Map of Nigeria showing the sampled Area (States in the Niger Delta Region)

Data Collection

Participants

From research (Bovwe *et al.,* 2016) Nigeria as a nation is faced with relatively the same nature of generated solid waste and managing these generated waste efficiently needs the input of experts both in practice and research. Thus, the targeted sample population for data collection with reference to this study is strictly limited to practicing and registered environmental professional, members of environmental associations/institutions both local and international with a minimum qualification of a post graduate degree in environmental engineering and management within Nigeria. This is due to their level of experience both in research, practice and policies as regards to solid waste management and sustainable development of Nigeria.

Questionnaires

The questionnaire was structured in such a way as to get the best information from the respondents. It was structured with reference to the recognized three main components of integrated solid waste management using systems approach with the aim of making pair-wise comparisons between various components and elements influencing the efficient management of generated solid waste within Nigeria inferred from research, practice and literature. The comparison scale as proposed by Saaty (2008) is used as the rating scale by the respondents (experts). Table 1 presents the judgments rating scale.

Table 1. Comparison/Judgment Scale

Scale of relative importance	Verbal/Logical Judgments	Explanations
1	Equally preferred	Two activities contribute equally to the objective.
2	Equally to Moderately	When a compromise is needed.
3	Moderately preferred	Experience and judgments slightly favour one activity over the other.
4	Moderately to strongly	When a compromise is needed.
5	Strongly preferred	Experience and judgments slightly favour one activity over the other.
6	Strongly to very strongly	When a compromise is needed.
7	Very strongly preferred	An activity is strongly favoured, and its dominance is demonstrated in practice.
8	Very strongly to extremely	When a compromise is needed.
9	Extremely preferred	The evidence favouring one activity over another is of highest possible order of affirmation.

Source: Saaty (1980)

Procedures

The sampling procedures used in data gathering for this study were Experts sampling & Mixed purposive sampling (also referred to as judgment sampling) techniques (Nwaogazie, 2011). This procedure of sampling is chosen due to the qualitative nature of the study. It is a non-probabilistic sampling technique that is based on specific purpose rather than randomly. A total of 150 questionnaires were distributed both in hard copies and soft copies, 72 responses were received; 28 questionnaires were filled wrongly and incompletely, 25 questionnaires were rejected due to inconsistency in judgment of criteria by respondents and 19 questionnaire responses were used for the analysis.

Data Analysis

Analytic Hierarchy Process (AHP) was used with regards to systems approach for efficient solid waste management system to assess the collected data. According to literature (Brunelli, 2015), AHP which was developed by Thomas Saaty is also a multi-criteria decision making tool based on a theory of relative measurement. It uses hierarchical structures to model problems (starting with objectives, criteria, sub criteria, and alternatives) and then develop priorities for alternatives based on the user (usually experts' opinions) to aid decision making when faced with a complex problem having multiple conflicting and subjective criteria. The AHP process modelling procedure usually involves the following basic steps: i) Problem modelling; ii) Weights valuation; iii) Weight aggregation; iv) Consistency check; and v) overall rating or prioritization.

Problem Modelling

With respect to systems approach for efficient solid waste management, two models were proposed by this study (see Figures 2 & 3). Model 1 comprises of 3 hierarchical structure and it is supported on the absolute measurements of the proposed alternatives. While Model 2 is made up of 4 hierarchical structure and is supported on the relative measurement of proposed alternatives. For both proposed models the first hierarch tells one about the objective of the model (which is efficient solid waste management) while the second hierarchy presents the criteria influencing the achievement of efficient solid waste management, it comprises of the outlined aspects (Social Aspects (C1); Political/Legal Aspects (C2); Economic Aspect (C3); and Environmental Aspect (C4)) of solid waste management with regards to systems approach. With respect to model 1 each criteria is preceded with various solution alternatives as suggested by experts within the study area while in model 2 each criteria is preceded with, and shared the same sub criteria which also has the same solution alternatives as suggested by experts' opinions.

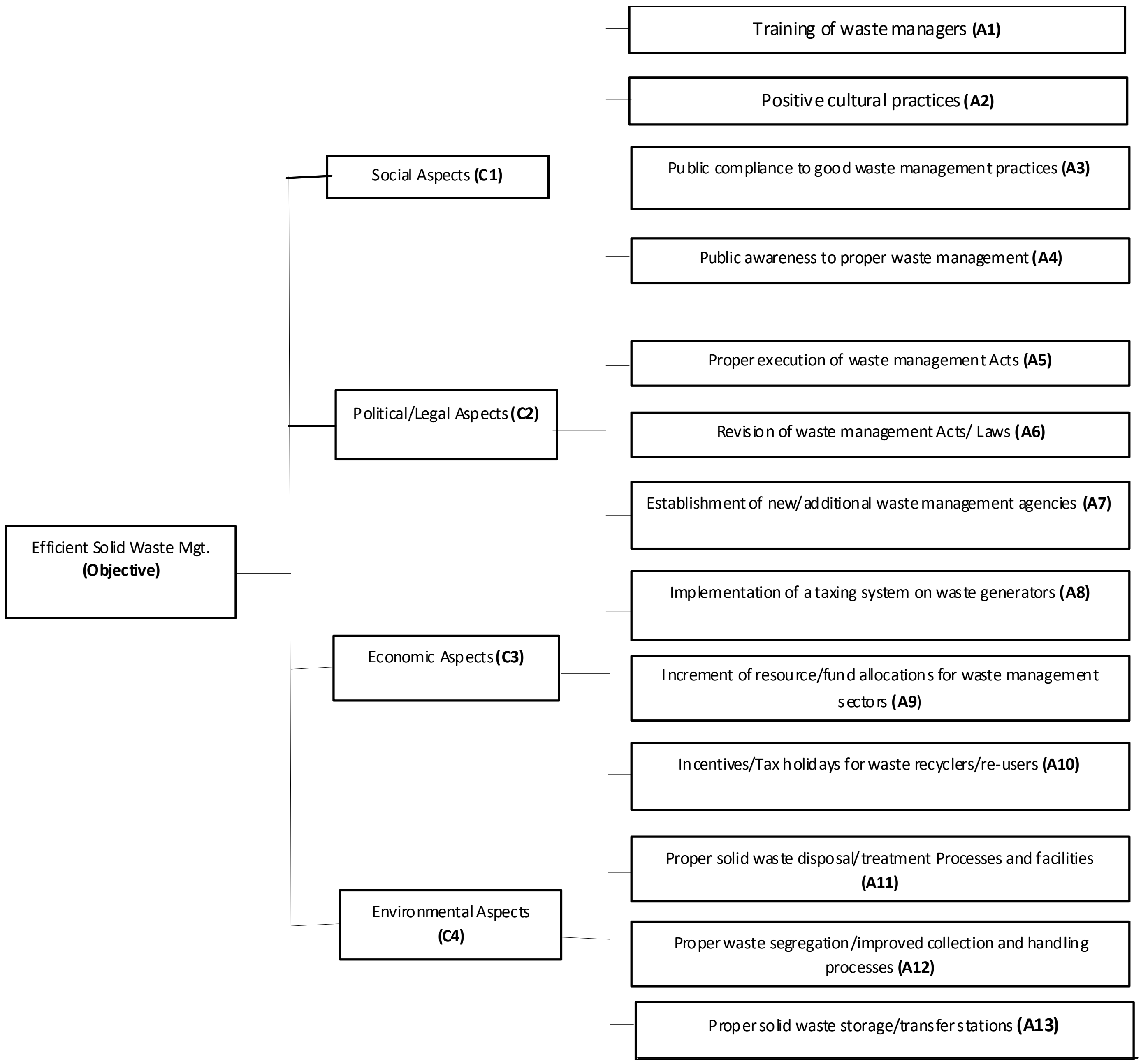


Figure 2. Proposed Hierarchical Structure of Model-1(Absolute Measurement of Proposed Alternatives)

Weights valuation

The weight valuation starts with the pairwise comparisons of the various elements at each hierarchical level (i.e. criteria and sub-criteria, respectively) by the respondents. These values are the inputs of the AHP modelling process used to set up a comparison matrix for analysis of the relative priority of each alternative. AHP uses the eigenvalues and eigenvectors of the pairwise comparison matrix (Saaty, 1980; Alexander, 2012). Equation (1) presents the structure of a pairwise comparison *matrix, A.*

$$A = \left(a_{ij}\right)_{n\times n} = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{21} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix} \quad \text{……… (1)}$$

From Saaty’s theory, each entry from the experts represents the ratio between two weights (see Equation 2)

$$a_{ij} \approx \frac{w_i}{w_j} \quad \forall i, j. \qquad \text{(2)}$$

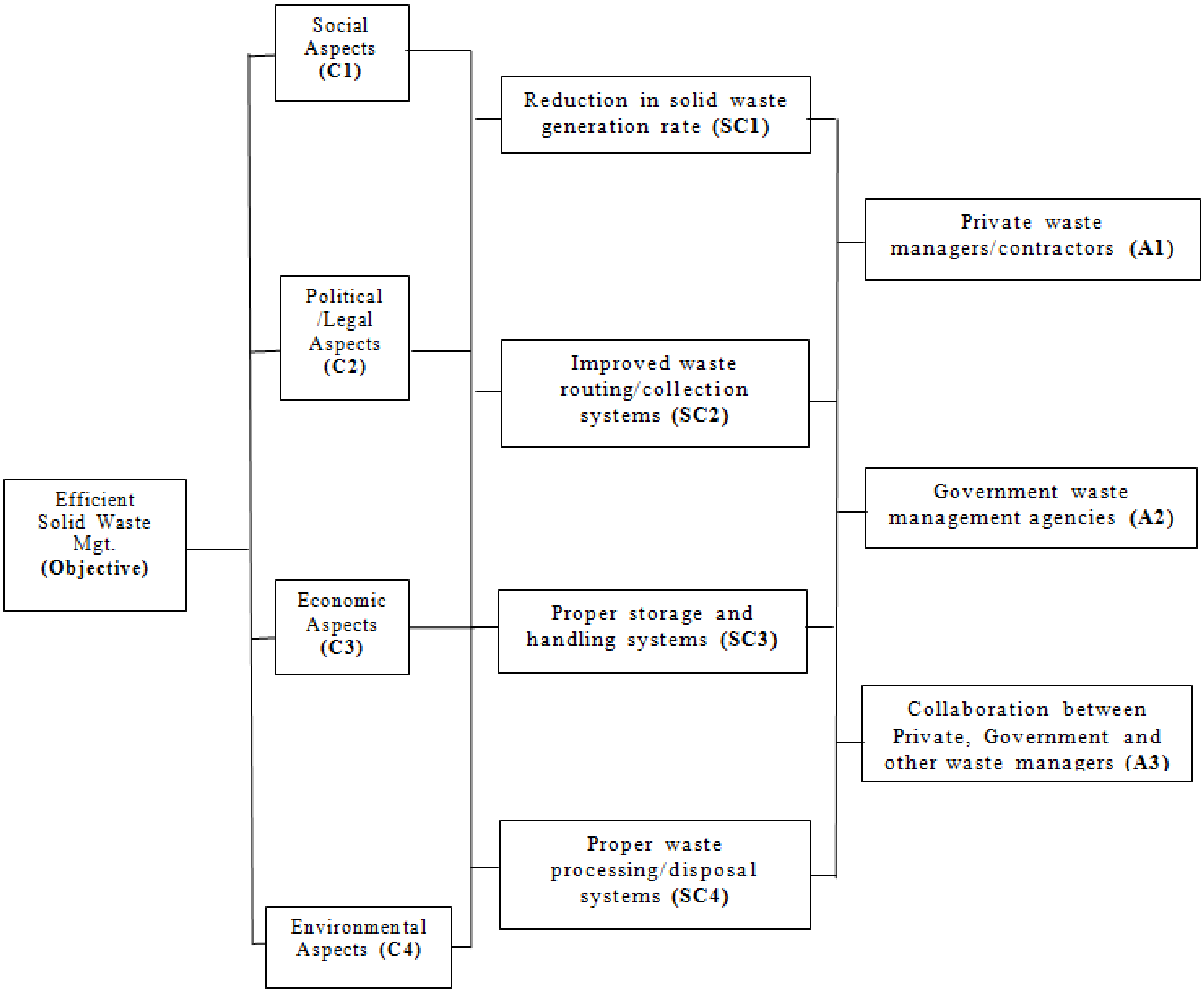


Figure 3. Proposed Hierarchical Structure of Model-2 (Relative Measurements of Proposed Alternatives)

From Equation (2), the matrix A (Equation 1) can be expressed as:

$$A = \left(\frac{w_i}{w_j}\right)_{n\times n} = \begin{pmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{pmatrix} \qquad \text{(3)}$$

From Equations (2) & (3), it follows that matrix A will be:

$$A = \begin{pmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & 1 \end{pmatrix} \qquad \text{(4)}$$

Using Equation (4), the priority (weight) vector for criterion *j* by each respondent is given by Equation (5) as:

$$w_j = \frac{1}{n}\sum_{k=1}^{n}\left(\frac{a_{jk}}{\sum_{k=1}^{n} a_{jk}}\right) \qquad (5)$$

Weight aggregation

In the context of reality, effective decisions are often made by group of people, committees, board teams of experts (as in the case of this study), etc. The weight aggregation of this group usually account for possibly different opinions of members of the group. In order to aggregate the opinion of each member of the group (respondent) and derive a priority vector $\boldsymbol{w^G}$**, t**here are two basic methods according to Forman and Peniwati (1998). These methods are:

- Aggregation of Individual Judgments (AIJ); and
- Aggregation of Individual Priorities (AIP).

The difference between the two methods is the stage where the aggregation is made. In AIJ, the aggregation occurs before the elicitation of the priorities while for AIP the aggregation is made after the derivation of the individual priority vectors. By using functional analysis, it was proven by research (Ssebuggwawo *et al.,* 2009) that the only meaningful and non-trivial aggregation method is the weighted geometric mean. With respect to this study the aggregation of individual judgment (AIJ) was applied for the weight aggregation of the respondents.

Let $w^{[k]} = \left(w_1^{[k]}, w_2^{[k]}, w_3^{[k]}, \dots, w_n^{[k]}\right)$, where $w_i^{[k]} > 0, \sum_{i=1}^{n} w_i^{[k]} = 1$, be the priority (weight) vector of the k-th respondent (from Equation 5), also let r = number of respondents, and $1 \le k \le r$. Then the group pair-wise (judgment) matrix, using geometric mean is given by:

$$A^{[G]} = \left(a_{ij}^{[G]}\right), \text{ where } a_{ij}^{[G]} = \prod_{k=1}^{r}\left(a_{ij}^{[k]}\right)^{\beta_k} \quad , \; i, j \in \{1, n\} \qquad (6)$$

Where β_k = weight of the k-th respondent in contributing to the group decision which for this study is taken as 1 for each respondent. From Equation (6), the group priority vector is finally assembled as:

$$w^{[G]} = \left(w_i^{[G]}\right), \qquad where \;\; w_i^{[G]} = \left(\prod_{j=1}^{n} a_{ij}^{[G]}\right)^{1/n} \qquad i, j \in \{1, n\} \qquad (7)$$

Consistency Check

To validate if the respondents' judgments are consistent, the consistency of the comparison matrices at each level of the hierarchy is checked using the value of the consistentcy ratio, *CR* which is given as:

$$CR = \frac{CI}{RI_n} \qquad (8)$$

Where *CI* = consistency index (see Equation 9), *RI* is the random index of the average consistency index of 500 randomly filled matrices as proposed by Saaty (Ishizaka and Labib,2011). Table 2 presents the calculated random indices for various dimension of a matrix

$$CI = \frac{(\lambda_{\max} - n)}{(n-1)} \qquad (9)$$

Where $\lambda_{\max}$ = maximum eigenvalue, n = dimension of the matrix

Table 2. Random indices (*RI*)

n	3	4	5	6	7	8	9	10
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Source: Ishizaka and Labib (2011)

If resultant CR is less than 10%, then the matrix is considered as having an acceptable consistency, if otherwise, the priority judgment of the respondent is not accepted on the basis of inconsistencty, however, and the criteria should be re-evaluated. Aguaron and Moreno-Jimenez (2003) proposed a threshold that provides an interpretation of the inconsistency threshold analogous to CR = 10% for Geometric Consistency Index (GCI): GCI = 0.3147 for n = 3, GCI = 0.3526 for n = 4 and GCI = 0.370 for n > 4. However, the geometric consistency index (GCI) for group decision as in the case of this study is computed as:

$$GCI = \frac{2}{(n-1)(n-2)}\sum_{i<j}\log^2\left(e_{ij}\right), \quad where, e_{ij} = a_{ij}\frac{w_j}{w_i}, i, j \in \{1, n\} \qquad \text{.......... (10)}$$

Overall rating or Prioritization

The overall rating is obtained by means of a linear additive function (Martinez Raga *et al.,* 2014), in which the relative priority for an alternative are multiplied by the importance of the corresponding criteria and summed over all criteria.

RESULTS AND DISCUSSION

Taking Model-1, with respect to the objective (efficient solid waste management), the resultant aggregation of the various individual respondent on applying Aggregation of Individual Judgment approach (AIJ) using Equation (6) is as presented in a 4x4 matrix (taken as Equation 11|)

$$A^{|G|} = \begin{pmatrix} & C1 & C2 & C3 & C4 \\ C1 & 1.00 & 1.53 & 2.33 & 0.37 \\ C2 & 0.65 & 1.00 & 0.72 & 0.54 \\ C3 & 0.43 & 1.39 & 1.00 & 0.18 \\ C4 & 2.70 & 1.84 & 5.43 & 1.00 \end{pmatrix}_{4x4} \qquad \text{.......... (11)}$$

From Equation (11), by dividing each column-entry by its respective column-sum and applying Equation (7) yields the Eigenvector (prioritized judgment) as presented in Equation (14). That is:

$$Column\ sum: \left.\begin{matrix} C1 = (1.00 + 0.65 + 0.43 + 2.70) = 4.78 \\ C2 = (1.53 + 1.00 + 1.39 + 1.84) = 5.76 \\ C3 = (2.33 + 0.72 + 1.00 + 5.43) = 9.48 \\ C4 = (0.37 + 0.54 + 0.18 + 1.00) = 2.09 \end{matrix}\right\}$$

.... (12)

Dividing each column-entry by its respective column - sum yields:

$$w^{|G|} = \begin{pmatrix} & C1 & C2 & C3 & C4 \\ C1 & 0.21 & 0.27 & 0.25 & 0.18 \\ C2 & 0.14 & 0.17 & 0.08 & 0.26 \\ C3 & 0.09 & 0.24 & 0.11 & 0.09 \\ C4 & 0.56 & 0.32 & 0.57 & 0.48 \end{pmatrix}_{4\times4} \qquad \text{.......... (13)}$$

Applying Equation (7), yields the Eigenvector (prioritized judgment) as presented in Equation (14), e.g. consider row-1 of Equation (13):

$$w^{|G|} = \sqrt{\prod_{j=1}^{n} a_{ij}^{|G|}} \quad = \sqrt[4]{(0.21\times0.27\times0.25\times0.18)} = 0.2238$$

The computed value of 0.2238 represents row-1 taken as C1. Thus, C2 through C4 follow same row-wise computation, see Equation (14).

$$w^{|G|} = \begin{matrix} \\ C1 \\ C2 \\ C3 \\ C4 \end{matrix} \begin{pmatrix} Normalization \\ 0.2238 \\ 0.1575 \\ 0.1261 \\ 0.4926 \end{pmatrix} \quad \ldots\ldots (14)$$

C1 = Social Aspects; C2 = Political/Legal Aspects; C3 = Economic Aspect; and
C4 =Environmental Aspects

Same procedure is repeated for the alternatives A1 – A13 (*see Appendix A*) and the resultant output is as presented in Figure 4

Also, for Model-2, following same procedure as illustrated, Figure 5 presents the plots of the resultant output for the prioritization of the criteria (C1, C2, C3 & C4), sub-criteria (SC1, SC2, SC3 & SC4) and the alternatives (A1, A2 & A3) with respect to the objective (*see Appendix B*).

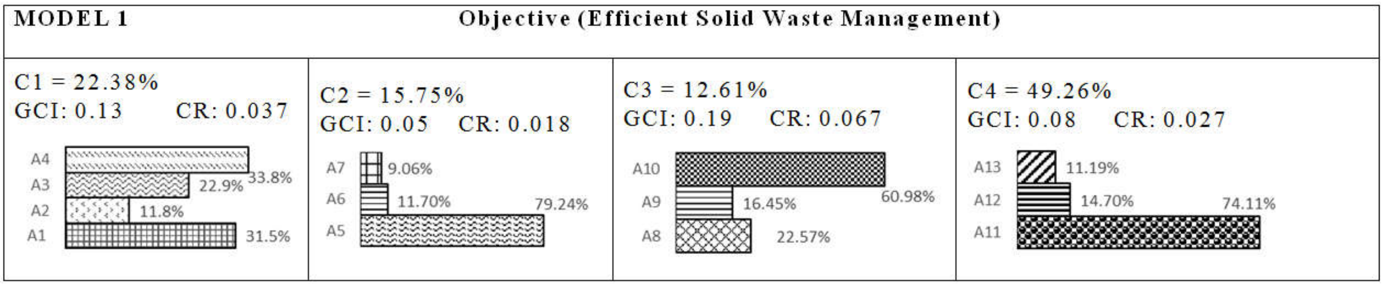


Figure 4. Resultant Output from Analysis of Model 1 (Absolute Measurement of Proposed Alternatives)

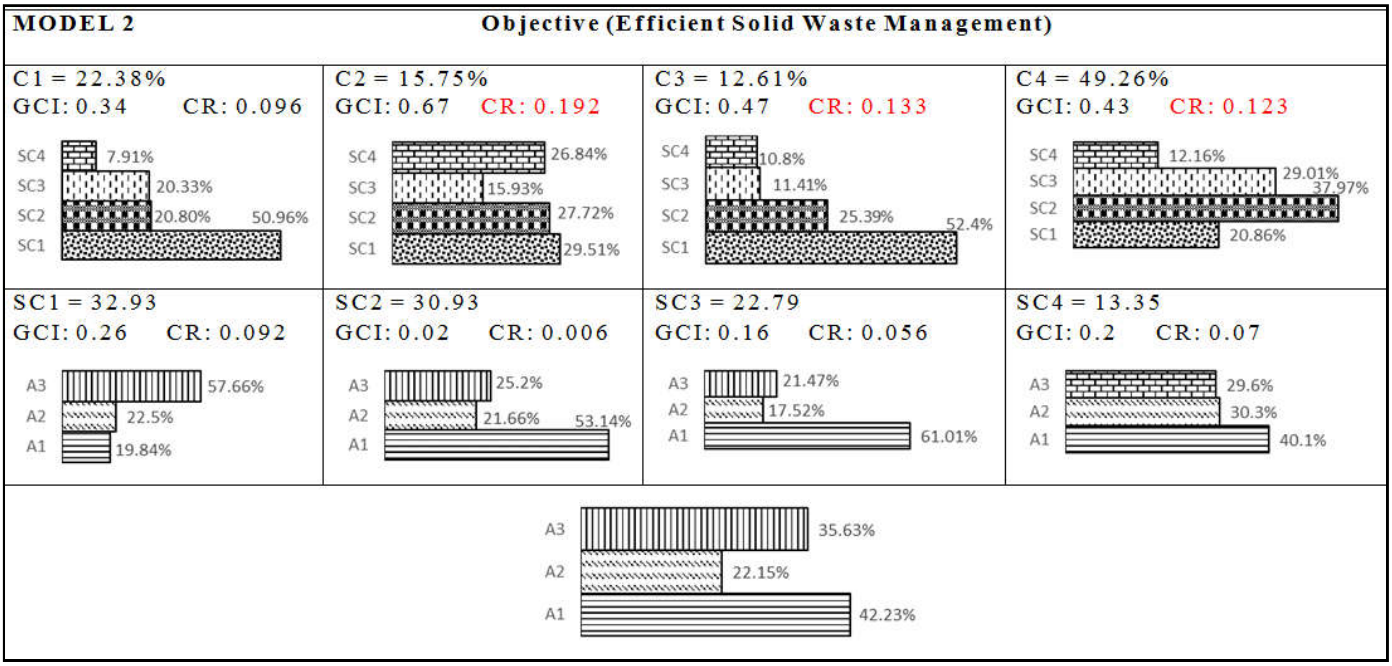


Figure 5. Resultant Output from Analysis of Model 2 (Relative Measurement of Proposed Alternatives)

DISCUSSION

The result on the application of Analytic Hierarchy Process (AHP) on the collected data in modeling the opinions of experts for the efficient management of solid waste yielded interesting results. For model-1 which was developed based on the absolute measurement of the proposed alternatives (A1 to A13) (see Figure 2), With respect to the Social Aspect (C1) and its influence to the efficient management of solid waste in Nigeria, it shows that educating the public on the proper management of solid waste contributes greatly (to the tune of 33.8%) in attaining efficiency of solid waste followed by the training of the various waste managers both in government and private waste management agencies (see Figure 4). The least contributing element to the efficient management with respect to the Social aspect (C1) was found to be the influence of cultural practices of Nigerians (11.8%). The Political/Legal Aspects (C2), from the analysis shows that the proper execution of waste management Acts (A5) by the Nigerian government will go a long way (79.2%) into making positive contribution for the efficient management of solid waste. The revision of waste management laws/ACTs (A6) and establishment of new waste management agencies (A7) makes little (9.06%) or no contribution to the attainment of efficiency in solid waste management in Nigeria (see Figure 4). Also, with regard to the Economic Aspects (C3) of solid with management from systems approach, it shows that when incentives and tax holidays (A10) are given to waste recyclers and agencies that are into re-use of waste materials it makes a great positive influence (60.98%) to efficient management of solid waste when compared with the increment of fund/resource allocated by the federal government to the waste management sector (16.45%). The implementation of a Taxing system (A8) by the federal government on waste generator also contributes notably (22.57%) to the efficient management of solid waste when compared with the increment of fund/resources allocated (A9) to waste management sector (see Figure 4). Finally, with regards to the Environmental Aspects (C4), the establishment of proper disposal of solid waste/treatment processes and treatment facilities (A11) influences the efficient management of solid waste in Nigeria greatly (74.11%) compared with the establishment of proper waste storage/transfer stations (A13) (11.19%) and followed by the proper segregation and improved waste collection and handling processes (A12) (see Figure 4). Model-2 from the analysis presented a more interesting result, the analysis from the modeling of experts opinions with regard to the Sub-criteria (SC1 to SC4) and their influence on the major criteria such as the Political/Legal Aspects (C2), Economic Aspects (C3) and Environmental Aspects (C4) showed level of inconsistency (see Figure 5) and as such cannot be used for the modeling of the experts opinion for efficient solid waste management (Gamukama et al., 2015). Ignoring the relative inconsistency, the global priority judgment showed that the involvement of private waste management agencies and contractors alone is the preferred choice for efficient waste management for Nigeria, followed by the synergic contribution of government and private waste management agencies (see Figure 5). However, with regard to the Social Aspects (SC1), the reduction of solid waste generated (SC1) ranks the best solution (50.96%) to efficient solid waste management in Nigeria followed by improved waste routing/collection system (SC2) which ranked approximately the same (20.80%) with the proper storage and handling system of generated solid waste (SC3) (see Figure 5). From the analysis it also shows that the best alternative to achieve the effective reduction of the generated solid waste with improved routing/collection systems, and the proper storage and handling system is through the engagement of the collaboration between both the private waste managing agencies and the federal government (A3).

Conclusion

Based on the study carried out the following conclusion can be drawn

- Applying Analytic Hierarchy Process into the modeling of experts opinion for efficient solid waste management presents a platform where experts make their individual judgment on the various elements of a solid waste management system taking advantage of their experience , level of practice and research;
- The analytic hierarchy process aggregates the individual priority judgment on efficient solid waste management of experts and come up with a global priority judgment;
- In Nigeria, efficient solid waste management (57.66%) can be achieved with the collaborator effort of the private sector and government waste management; and Finally, applying Systems approach to solid waste management, a remarkable level of efficiency can be obtained with regards to the social aspects, political/legal aspects, economic aspects and environmental aspects through:
  - Increase in public awareness on the proper waste management practices(33.8%);
  - Training of waste mangers both in government and private agencies(31.5%);
  - Proper execution and implementation of waste management Acts (79.24%)
  - Giving of incentives and tax holidays to waste recyclers/ re-users(60.98%);
  - Proper solid waste disposal and treatment process/facilities(74.11%); and
  - Reduction in the rate of solid waste generation rate within the Nation (50.96).

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