USE OF ANALYTIC HIERARCHY PROCESS (AHP) AS AN INSTRUMENT TO DEVELOP A SOLID WASTE MANAGEMENT ASSESSMENT TOOL

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Abstract: *The aim of this paper is to evaluate the feasibility of Analytic Hierarchy Process (AHP) as a data collection instrument in developing a solid waste management assessment tool. AHP is a quantifying tool that provides an effective and precise means of choosing options evident in many disciplines such as waste management where priority scales measure elements in relative terms. The procedure is performed using Expert Choice software. A structured questionnaire survey was employed to obtain data from waste management practitioners across four work sectors and five locations in Nigeria, which adopted AHP for data collection and analysis. A solid waste management assessment function was derived that can be employed to establish the status of management strategies.*
Keywords - *Analytic Hierarchy Process, solid waste management, assessment, practitioners, Expert Choice*

I. INTRODUCTION

AHP is a theory of measurement, originally devised by Saaty (1980) that employs paired comparisons and relies on the judgments of practitioners or stakeholders to derive priority scales for factors of an issue or system (Saaty, 2008). It is a quantifying tool and a multi-criteria technique that provides an effective and precise means of choosing options by measuring both tangibles and intangibles; qualitative and quantitative factors evident in many disciplines such as waste management (Saaty, 1990; Soma, 2003; Saaty 2008). The priority scales measure elements in relative terms. The comparisons are made using a scale of absolute judgments that represent how much one element dominates another with respect to a given attribute. The judgments may be inconsistent, and how to measure inconsistency and improve the judgments to obtain better consistency is taken into account by AHP (Bello-Dambatta *et al*., 2009).

A) Solid Waste Management

Solid waste management assessment is a complex multi-dimensional process with many potential management options such as incineration, gasification and composting as well as many system elements that include temporary storage, collection, transportation and final disposal. Assessments are required to make effective and informed decisions in the selection of preferred options. The aim of this paper is to evaluate the feasibility of Analytic Hierarchy Process (AHP) as a data collection instrument in developing a solid waste management assessment tool.

B) General application

AHP has been applied effectively in many disciplines in complex decision and evaluation problems involving several objectives and multiple stakeholders as the approach is flexible, explicit and easily traceable (Contreras et al., 2008). In the case of waste management, relatively new studies have been carried out using AHP as a tool (Brent *et al*., 2007; Contreras *et al*., 2008; Garfi *et al*., 2009; Lin *et al.,* 2010). Its extensive use in environmental management as outlined in Table 1 has shown that it can be used to resolve differences of opinion among various stakeholders in the selection of preferred option(s) in waste management. Generally, multi-criteria techniques seek to assist in identifying feasible alternatives that attempt to reach balanced stakeholder priorities of multiple goals (Soma, 2003). A variety of multi-criteria analysis techniques such as ELECTRA III, PROMETHEE I and II, multi attribute utility theory methods and SMART have been used in dealing with environmental problems (Morrissey and Browne, 2004; Contreras *et al*., 2008). They involve the systematic modeling of decision maker's preferences to explicitly approve a choice between often conflicting objectives (Wilson *et al*., 2004). AHP has an intuitive appeal to users because of its hierarchical feature that allows easy and natural structuring of the decision problem (Ramanathan, 2001; Saaty 2008; Leung *et al*., 1998). It also increases the overall understanding of the issue at hand among participating stakeholders as a result of the hierarchy (Soma 2003). Although over-simplification might occur with the use of AHP, it has the ability to simplify and condense reality into a framework that can be used for assessment by organizing and structuring complex realities including situations with scarce data (Soma 2003). This is invaluable in developing countries where reliable quantitative data is generally not readily available (Sha'ato *et al.,* 2007). Furthermore, the decision process using AHP is found to be systematic and conserves time. (Vaidya and Kumar, 2006).

Table 1: Some studies employing AHP

Reference	Country	Subject	Actors
Abba et al., 2013	Malaysia	Environmental impacts	-
Chun-hsu Lin et al., 2010	Taiwan	E-Waste policy	18
Arnette et al., 2010	Virginia, US	Watershed management	33
Garfi et al., 2009	Algeria	Waste management	20
Contreras et al., 2008	Boston, USA	Waste management	-
Sambasivan and Fei, 2008	Malaysia	EMS	22
Wattage and Mardle, 2008	Srilanka	Fisheries Management	200
Contreras et al., 2008	Boston, USA	Waste management	-
Sambasivan and Fei, 2008	Malaysia	EMS	22
Wattage and Mardle, 2008	Srilanka	Fisheries Management	200
Brent et al., 2007	S/Africa; Lesotho	SD & Waste Management	11
Shin et al., 2007	Korea	Nuclear projects	48
Soma, 2003	Trinidad & Tobago	Fisheries Management	-
Lai et al., 2002	Hong Kong	Multi-media	622
Leung *et al*., 1998			34

The nine-point comparison scale used to generate quantitative measurement is somewhat technical and requires a description (Soma, 2003). In addition to the relative importance of criteria determined by the procedure, relative contributions of the factors influencing the criteria are also decided by AHP (Saaty, 2008; Leung *et al*., 1998). The sophisticated and user-friendly software developed for AHP, Expert Choice, is quick and has the multiple function of building up the issue, data processing and analysis including inconsistency measurement (Leung *et al*., 1998; Soma, 2003). Also, it does not require specialists for implementation (Dodgson *et al*., 2009).

Despite its growing application in many fields (Vaidya and Kumar, 2006), AHP had an initial limitation of ranking irregular that can presently be avoided by employing the geometric mean and the weighted geometric mean rule that preserves the underlying mathematical structures (Saaty, 1990). However, proving this mathematically is beyond the scope of this study. The AHP procedure is a complete aggregation method of the additive type and compensation between good scores on some criteria and bad scores on others during the aggregation can lead to loss of important information (Macharis *et al*., 2004). However, the scores of the indicators used are generally provided to identify areas of strength and weaknesses to counteract this negative feature of the process.

II. METHODOLOGY

A structured questionnaire survey using AHP as data collection instrument was employed in this research to determine the preference of practitioners on issues of sustainable waste management. As a multi-criteria technique, it has a practical nature that takes into account the complexity of different aspects and interests that are often conflicting within and outside the waste management system (Zahedi, 1986; Leung *et al*., 1998). The complexity of the waste management exists due to diversity of its stakeholders and their opinions and large amount of factors that influence the system. The issue of participation and acceptance of results by stakeholders is one of the most important aspects and objectives that must be considered in sustainable waste management. Effective waste management is dependent upon achieving informed consensus amongst interested parties and can be realized simply with the application of AHP (Petts, 1994; Garfi *et al*., 2009).

AHP – The procedure

The AHP procedure involved the following steps (Zahedi, 1986; Rangone, 1996):

- Developing a hierarchical structure of the decision problem in terms of overall objective, criteria, sub-criteria and decision alternatives
- Determining, on pair wise basis, the relative priorities of criteria and sub-criteria that express their importance in relation to the element at the higher level
- Estimating the relative weights of decision elements using the ‘eigenvalue’ method, which

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indicates the significance of each criteria and principle

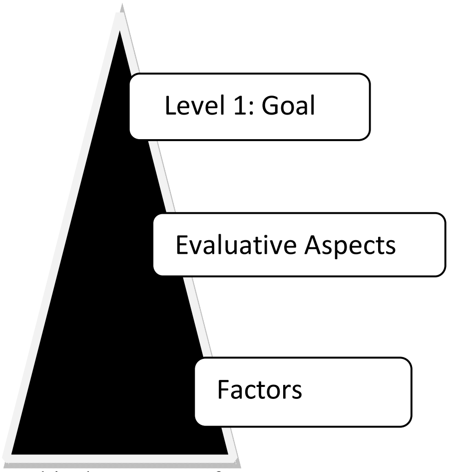

Figure 1: Hierarchical structure of waste management Sustainability Assessment

A) Hierarchical structure

A hierarchy is defined as a stratified system for organizing ideas, people or things whereby each element of the system, except the goal of the hierarchy falls in a level and is subordinate to other elements in the levels above (Saaty, 1980). The hierarchical structure is a graphical representation that generally provides better understanding of the issue(s) at hand. They are validated by ensuring the structure is logical and complete (Saaty and Shih, 2009). The hierarchy in this study was achieved by the breakdown of sustainable development with respect to solid waste management into aspects at the second level and factors at the third. Elements that have the same properties are grouped together and are related according to their influence on the next level

B) Pair wise comparisons

The AHP uses pair wise comparisons of elements to pair off all individual aspects and factors, and the end results compiled into a decision matrix (Bello-Dambatta *et al*., 2009). It assigns a greater rating to elements with greater importance or impact. 9 on the left while 9 on the right depict extreme importance of administrative aspect over environmental aspect. An example of a pair wise comparison of two aspects (environmental versus administrative aspects) is shown in figure 4.2 with an accompanying scale interpretation. In the same way, 7 indicates very strong importance, 5 strong, 3 moderate and 1 equal importance of the two elements under consideration (Saaty, 2008). This is carried out by expert choice.

C) Expert choice software

The elements compared at a peer level using the pair wise comparison are transferred from the questionnaire survey into the expert choice software for each participant to determine weights of elements. To determine the relative importance of three peer-level elements presented in Figure 3.3 for example, a 3 x 3 matrix is formed and weights are determined using the eigenvector matrix (Al-Harbi, 2001; Ngai and Chan, 2005).

Table 2: Criteria for Environmental aspects

Air Quality Water Quality								Q10
9	7	5	3	1	3	5	7	9
Significantly more important Significantly more important				Equal				

Air Quality Resource conservation								Q11
9	7	5	3	1	3	5	7	9
Significantly more importance Significantly more important				Equal				

Water Quality Resource conservation								Q 12
9	7	5	3	1	3	5	7	9
Significantly more important Significantly more important				Equal				

With n being the number of elements in a level, n(n-1)/2 number of judgments are required to develop the matrix (Al-Harbi, 2001). In this example, the three judgments are required to compare air quality, water quality and resource conservation presented in Figure 3.3 (Al-Harbi, 2001).

Table 3: The matrix determined from the judgment is:

	Air	Water	RC
Air	1	1	1/3
Water	1	1	1/3
RC	3	3	1

Reciprocals are automatically assigned in each pairwise comparison and normalized to give (Al-Harbi, 2001);

	Air	Water	RC
Air	$^1/_5$	$^1/_5$	$^1/_5$
Water	$^1/_5$	$^1/_5$	$^1/_5$
RC	$^3/_5$	$^3/_5$	$^3/_5$
Sum	1	1	1

The normalized principal Eigen vector is obtained from;

Air	$^1/_3$	$^1/_5$	$^1/_5$	$^1/_5$	$^1/_5$
Water		$^1/_5$	$^1/_5$	$^1/_5$	$^1/_5$
RC		$^3/_5$	$^3/_5$	$^3/_5$	$^3/_5$

Therefore air quality and water quality have weights of 0.2 each while resource conservation has 0.6 that is three times more important than air or water quality.

D) Participants

Four groups of practitioners for the questionnaire administration and AHP application are Federal Government, state/local government sector, private sector – formal and informal, and academic sector.

The sectors of practitioners outlined represent individuals whose professional knowledge and value judgments are required to achieve realistic weightings of factors and aspects governing any waste management scheme. These four groups have been adopted in a combination of one two, three or all four in the studies outlined in Table1. Value judgments are expressions of preferences among alternatives based on priorities or trade-offs (Otway and von Winterfeldt 1992).

In line with recent practice, practitioners involved in studies were selected based on one or more of the following criteria (Noble, 2004): previous experience in at least one of the system components; current or previous leadership or management role in one or more of the specialty areas of the waste management scheme; representation of four work sectors evidenced in waste management in Nigeria; representation of affected geographic area; at least five years of combined and combined and professional experience in Environmental and/or waste management; publications, participation in professional meetings and symposium and current or previous memberships on environmental and/or waste management bodies; practicality given time and resources available

Adequacy of the size of sample group is demonstrated by studies carried out where expert judgments are employed demonstrated in table 4.1. According to Turnoff (1975), a participant number of ten is sufficient to make the required judgment(s) (Noble, 2004) particularly for AHP as supported by Sambasivan & Fei (2008).

E) Study locations

The survey was carried out in five locations to capture Nigeria's multiple ethnic groups and diverse cultures; Abuja, Lagos, Kaduna, Maiduguri due to apparent differences in waste management practices across the country. In addition, legislation between individual states varies due to some degree of autonomy given to the state governments.

The cities listed are major cities in Nigeria with Kaduna representing the guinea savannah climatic zone, which covers approximately 40% of the country (Adejuwon, 2006). Port-Harcourt covers the mangrove swamp zones of the extreme south while Lagos in the south-west represents the fresh water swamp zones. The sudan and sahel savannah is represented by Maiduguri in the north-east while the montane (Adejuwon, 2006). Abuja situated within the guinea savannah climatic zone is adopted as the federal capital territory

F) The structured questionnaire survey

The structured questionnaire administration adopted in this study consists of the researcher obtaining responses to a set of consistent questions from practitioners and then circling their preferences. The set of questions are the same for all researchers and follow the same sequence. An explanation of the purpose of the investigation and pair wise comparison method of selecting preferences and the measure of their intensity is also described prior to the questions. The Respondents are given an exact copy of the questionnaire during the questionnaire administration.

G) Data processing and analysis

Data from individual questionnaires was analyzed using AHP technique with Expert Choice software to determine the individual weightings assigned to aspects and factors by practitioners. Statistical analysis was used to generate the overall weightings of the aspects and factors, which was used to derive a function – the sustainability Index function. The non-parametric statistical analysis – Kruskal Wallis using Minitab 15 was applied to test for differences between sectors and locations.

III. RESULTS AND DISCUSSION

Data was effectively collected from practitioners using the AHP as an instrument of data collection. In addition, the data was analyzed using the AHP procedure to show the overall significance apportioned to each aspect and factor that was employed to derive a sustainability function to appraise waste management strategies.

A) The solid waste management sustainability assessment tool and function

An assessment tool and a function were developed that can be used to establish an index of a given solid waste management strategy. AHP was applied using Expert Choice software to establish the individual weightings assigned by practitioners to sustainability assessment aspects and factors. The median weightings allocated by the individual practitioners are obtained for each factor and aspect using descriptive statistics to establish the overall weightings. Figure 4.1 shows overall weightings with aspects at the second level and factors at the third from the top. Results include the survey re-administered to respondents with data inconsistencies of over 10% as prescribed by AHP.

i) Sustainability assessment function

The overall weightings in the hierarchy are presented as a function of the sustainability index for the assessment of solid waste management strategies in Equation 1.

$$\mathrm{SI} = 0.065\mathbf{I}_{1i} + 0.103\mathbf{I}_{2i} + 0.103\mathbf{I}_{3i} + 0.07\mathbf{J}_{1i} + 0.073\mathbf{J}_{2i} + 0.073\mathbf{J}_{3i} + 0.064\mathbf{J}_{4i} + 0.078\mathbf{K}_{1i} + 0.053\mathbf{K}_{2i} + 0.062\mathbf{K}_{3i} + 0.037\mathbf{K}_{4i} + 0.11\mathbf{L}_{1i} + 0.11\mathbf{L}_{2i} \qquad (1)$$

Table 4: Parameters in Equation one

Environmental indicators	Administrative indicators	Social indicators	Economic indicators
I_{1i} - Air quality indicators	J_{1i} - Policy indicators	K_{1i} - Health indicators	L_{1i} = Job creation indicators
I_{2i} - Water quality indicators	J_{2i} - Management indicators	K_{2i} - Service quality indicators	L_{2i} = Total cost indicators
I_{3i} - Resource conservation indicators	J_{3i} - Responsibility indicators	K_{3i} - Stakeholder involvement indicators	
	J_{4i} - Technologies indicators	K_{4i} = Equity indicators	

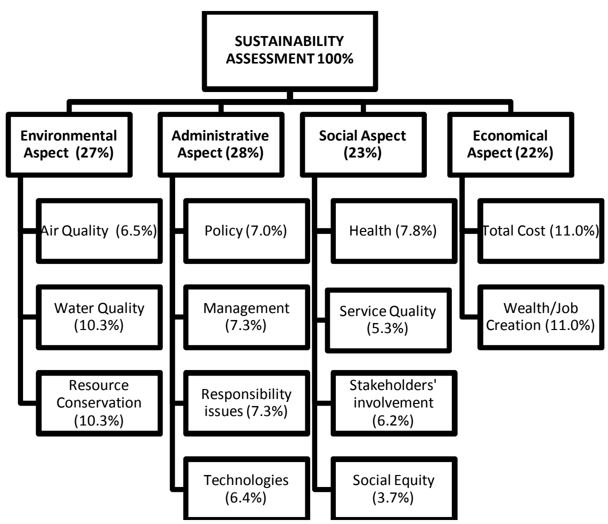

Figure 2: The Hierarchical structure with weightings (Source - Original)

IV. CONCLUSION

AHP was applied effectively in data collection and analysis to build up a solid waste management assessment function using the structured questionnaire survey. The survey was carried out across practitioners from four work sectors – academic, federal government, state government and the private sectors; and five locations – Lagos, Kaduna, Maiduguri, Port-Harcourt and Abuja. The study shows the potential of AHP as a suitable approach for developing an assessment tool in the field of solid waste management from to the function derived.

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