SUSTAINABILITY APPRAISAL OF WASTE MANAGEMENT IN NIGERIA: DEVELOPMENT AND EVALUATION OF AN INDEX BASED TOOL

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DEDICATION

This work is dedicated to my parents, **A'isha Garba Batagarawa** and **Lawal Tukur Batagarawa.**

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DECLARATION

I declare that the work presented in this *thesis* is, to the best of my knowledge and belief, original except as acknowledged in the text. The work was carried out in accordance with the regulations of the University of Portsmouth and the material has not been submitted, in part or in whole, for any other degree at this or any other university.

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ABSTRACT

Decision makers are continuously in search of a comprehensive yet simple means of assessing solid waste management to make effective and informed decisions. This is particular so for situations like Nigeria where streets are full of waste, many households have no waste collection services and a high rate of vehicle and equipment breakdown is recorded. Assessment is also crucial at a time when many waste management authorities are trying to embark on new revolutionary contracts with the private sector. Solid Waste Management assessment is a complex multi-dimensional process, involving multiple criteria and multiple actors and the many components that make up the system. Although various options such as incineration, gasification and composting are available as a solution for waste management, these options also add to the complexity of the situation in determining most preferred alternatives and decisions. In this study, an in-depth investigation of solid waste management in Nigeria is conducted by quantifying sustainable development to develop an assessment tool. Sustainable development with respect to solid waste management was broken down into its aspects and factors that influence those aspects in a hierarchy of three levels according to the procedure of analytic hierarchy process. Solid waste management practitioners across five locations representing Nigeria's multiple ethnic groups and diverse cultures and the climatic zones as well as four work sectors were surveyed. Data was obtained from a paired comparison based questionnaire survey using Analytic Hierarchy Process. A function was derived that illustrates the potential of SD as a tool for solid waste management assessment. General agreement across sectors was recorded but significant differences exist between regions. The regional difference highlighted indicates context as highly influential. Quick response and cooperation of participants suggests sympathy towards female researcher while slow contact establishment was recorded in Lagos despite an alliance with an indigene of the region. The function derived was adopted to evaluate the solid waste management strategy in Kaduna metropolis of Nigeria using a case study methodology. The accomplished assessment has shown that waste management strategies can be evaluated with the tool developed in this study. An index of **0.457** was established from the evaluation that employed the use of indicators, scoring and normalisation. High scores assigned to indicators will result in a high index, which suggests an effective strategy.

CONTENTS

LIST OF FIGURES

LIST OF PICTURES

LIST OF TABLES

1.0 OVERVIEW

1.1 INTRODUCTION

The main challenge of managing solid waste in generally in developed countries has shifted from ensuring minimum damage to public health and environment to the manner in which discarded resources are to be handled such that future generations are not deprived of its value (Chandak, 2010). Developing countries on the other hand are still battling with the protection of human health and well-being while attempting to conserve resources (Brunner and Fellner, 2007). However, many of the developed countries are still unable to decouple waste growth from economic growth with resulting economic and environmental burden driving the need to increase effective waste minimization and management (Fatta and Moll, 2003; Desmond, 2006). This applies to many member countries in the European Union (Fatta and Moll, 2003). The following sections give an overview of the chapters in the thesis.

1.2 SOLID WASTE MANAGEMENT

This section is an overview of Chapter 2 where literature on solid waste management especially in Nigeria is reviewed. The section also includes the review of literature on the methods used in assessing solid waste management strategies. Waste management is regarded as a public service where efficient collection and safe disposal of wastes are essential to public health and environmental protection (Cointreau-Levine, 1994). It has evolved from the simple transportation of waste to landfills to complex systems, including waste prevention and waste recycling as well as several waste treatment and landfill technologies (Salhofer *et al*., 2007). While developed countries have achieved the first aim of waste management of providing protection to human beings and the environment and are battling resource conservation, the health and well-being of humans still suffer from inadequate waste management systems in developing countries and the first objective still remains a main priority (Brunner and Fellner, 2007).

1.2.1 SOLID WASTE MANAGEMENT IN NIGERIA

In Nigeria, there is a steady increase in waste quantity and variety due to population growth and industrialisation (Imam *et al*., 2007) while the basic solid waste management system based on collection, transportation and disposal remains highly inefficient and ineffective, especially in the

urban centres (Ayotamuno and Gobo, 2004). Nigeria is the most populous and the tenth largest country in Africa with a population of over a hundred and fifty million people across a landmass of 923,768 square kilometres (WDI, 2010).

1.2.2 Legislation

Nigeria operates a three tiers system of government made up of federal, state and local government with distinct functions accorded to each tier based on constitution (Afon, 2007). The milestone Federal legislation on environmental protection in Nigeria was the decree 58 of 1988, which established the Federal Environmental Protection Agency (FEPA) to control the growing problem of waste management and pollution in Nigeria (Walling *et al*., 2004; Imam *et al*., 2008). Solid waste management is constitutionally the responsibility of the local government but the state government steps in to complement their efforts especially in state capitals such as Kaduna, Lagos and Port-Harcourt (Afon, 2007). Despite their effort, the solid waste management scheme in Nigeria is characterized by a system fraught with lack of accountability and refuse filled spaces, drains and roads (Dauda and Osita, 2003; Walling *et al*., 2004).

1.2.3 Solid waste generation and management elements

The estimated waste generated per person in a day is 0.49 kg with households accounting for 90% of the urban waste (Solomon *et al*., 2009). It has a high organic content consistent with waste generated in developing countries such as Ghana, China and Jordan and Palestine (Qdais, 2007; Al Khatib *et al*., 2010; Zhang et al., 2010; Fobil *et al*., 2010). The composition of waste in Nigeria suggests a recyclable content of over forty percent with recycling rate estimated at 8-22%, carried out by the informal sector (Wilson et al., 2009). Other disposal options are open dumping, open burning and composting (Dauda and Osita, 2003; Imam et al., 2008; Ogwueleka, 2009).

The waste is temporarily stored within households or at communal disposal sites in various sizes of bins, bin bags, baskets, buckets and directly on the ground at communal sites (Abdullahi *et al*., 2008). Highly irregular collection of co-mingled waste is carried out by the state/local government directly, via contractors and/or informal waste managers (Sangodoyin, 1993; Agunwamba, 1998; Dauda and Osita 2003; Abdullahi *et al*., 2008; Imam *et al*., 2008). More than 50% of the population dispose waste at communal sites, which are basically open dumps (Dauda and Osita, 2003). Waste is typically transported by lorries, tippers, loaders, trucks, tractors, push carts and wheel barrows (Dauda and Osita, 2003; Afon, 2007; Imam *et al*., 2008). Collection and transportation accounts for between 70-80% of total waste management cost in Nigeria (UNDP, 1998) mainly funded by the

government. Irregular collection and transportation of waste is partly attributed to frequent breakdown of vehicles and inadequate facility and equipment (Dauda and Osita, 2003; Imam *et al*., 2008; Adewole, 2009).

1.2.4 Awareness and attitude

Generally poor attitude towards waste management is recorded in literature (Imam *et al*., 2008; Adewole 2009). The local and state government responsible for raising awareness on solid waste management issues often adopt seminars, conferences, workshops, training sessions as the most common techniques in creating awareness observed in the course of the survey in addition to environmental management topics included within junior secondary schools syllabus (Uhuo and Zavodska, 2010).

1.2.5 Solid waste management assessment

Solid waste management assessment is undertaken to measure performance of a scheme with the main aim of improving existing strategy and practices (Anschutz, 2004). The methodologies commonly used are generally based on three models – cost benefit analysis (CBA), life cycle assessment (LCA) and multi-criteria analysis (MCA) (Morrissey and Browne, 2004). All aspects of solid waste management are estimated in monetary terms in the case of CBA while LCA focuses on environmental impacts (Morrissey and Browne, 2004). MCA approaches are used to identify single most preferred options and/or to rank options in decision making while taking into account often conflicting criteria usually involving a wide range of multi-disciplinary stakeholders such as solid waste management (Mendoza *et al*., 1999; Qureshi and Harrison, 2001; Morrissey and Browne, 2004; Dodgson *et al*., 2009).

1.2.5.1 Sustainability assessment of solid waste

Modern waste management presents a high level of complexity that requires many aspects to be considered for suitable solution that encapsulates both the current state of the environment as well as its potential to provide support for future generations (Jha and Murthy, 2002). There is an apparent need to develop a comprehensive assessment method that enables identification of the present waste management status while giving stakeholders an insight into the problem and a platform for discourse.

Sustainable waste management emphasizes a shift from waste disposal to other waste management options that includes energy and material recovery, waste reduction and reuse in

addition to the aim of decoupling increase in waste generation from economic growth (Chung and Lo, 2003; Fatta and Moll, 2003; Desmond, 2006). There is an agreement across the environmental and waste management field on the basic principles and elements of the concept as well as many of the criteria used in characterising or measuring the system (Van de Klundert, 1996; Tammemagi, 1999; Chung and lo 2003; Lang *et al*., 2007).

To evaluate waste management systems sustainably, the issue of quantifying sustainable development arises, which requires transparent and reliable measurement that must generally be agreed upon by stakeholders (Jha and Murthy, 2002; Joseph, 2006; Lang *et al*., 2007). While the generic principles of sustainable development consist of social, environmental and economic aspects, the administrative aspect has been evaluated in many studies involving waste management (Van de Klundert, 1996; Van de Klundert and Anschutz, 2001; Chung and Lo, 2002 Hayward and Gaskin, 2005; Desmond, 2006).

The objectives for environmental sustainability are summarized as rational resource consumption and reduction of environmental pollution (Chung and Lo, 2003; Den Boer *et al*., 2007; Hung *et al*., 2007; Roussat *et al*., 2007; Imran *et al.*, 2008). The administrative aspect encompasses policy, management, research and training, responsibility issues and technologies used to provide the waste management service (Van de Klundert and Anschutz, 2000; Walmsley *et al*., 2001). Social sustainability deals with ensuring human health and well-being in the present and future generations (Imran *et al*., 2008). Economically sustainable waste management takes into account all external costs into the total cost established for waste management (Imran *et al*., 2008).

1.2.6 RATIONALE AND AIMS OF STUDY

Solid waste management in Nigeria has received considerable attention mostly in the areas of waste quantity and quality (Sridhar *et al*., 1985; Adedibu 1988; Afon 2007; Afon and Okewole, 2007; Sha'Ato *et al*., 2007); a few on regulations and governance (Adedibu 1986; Oyelola and Babade 2008; Kalu *et al*., 2009; Nzeadibe 2010) and especially on the status of the existing strategy (Agunwamba, 1998; Dauda and Osita, 2003, Izugbara and Umoh, 2004; Ayotamuno and Gobo, 2004; Ajibade, 2007; Ajani 2008; Babayemi and Dauda, 2010); state of the environment (Akeredolu 1988; Olukesusi, 1988; Bammeke and Sridhar, 1989; Baumbach, 1995; Aluko *et al*., 2003; Olaniyan 2007; Anake 2009) and fewer regarding perception and awareness (Babayemi and Dauda, 2010; Longe *et al*., 2009). While work on systematic assessment of current strategy is non-existent, Abdullahi *et al*. (2008) proposed an appropriate management strategy that included all stakeholder categories operating in the existing scheme including the highly controversial informal

sector. Where waste management is assessed, the approach employed is usually not based on any particular methodology and is strictly qualitative (Agunwamba, 1998; Longe and Williams 2008; Imam *et al*., 2008; Adewole, 2009).

Although most management of waste strategies including that of Nigeria ascribe to sustainability, assessing progress towards this goal commonly carried out by use of indicators varies widely with no consistent tool or framework for application (Desmond, 2006). Some assessment tools have been proposed in Europe and Asia that have incorporated the desired social and administrative aspects while integrating various stakeholder groups and levels (Desmond, 2006) with some having a bias towards a particular issue (Van de Klundert and Anschutz, 2000) and therefore not considering the system holistically.

The main aim of this study is to quantify sustainable development with regards to solid waste management in an attempt to develop an assessment tool. The aims include establishing the current situation of waste management in Nigeria by generating an index to demonstrate the sustainability of an existing waste management scheme in a particular city and thereby appraising the applicability of the sustainability assessment model established. The objectives identified in achieving these aims are discussed in section 3.1.2.

1.3 METHODOLOGY

The strategy adopted to achieve the aims of this study detailed in Chapter three is outlined in this section. It primarily involved a structured questionnaire survey administered to solid waste management practitioners across Nigeria over a period of eleven months. The main aim of the survey was to corroborate the suitability of the concept and its broken down aspects and factors for evaluating solid waste management schemes and to illustrate the varying significances of the aspects and factors. Relevant literature on waste management was reviewed to appraise assessment methods and the current state of solid waste management particularly in Nigeria, which identified sustainable development SD as a suitable concept to build the assessment tool. The structured questionnaire survey adopted analytic hierarchy process (AHP) as the research instrument to collect data from waste management practitioners.

1.3.1 Analytic hierarchy process, AHP

Analytic Hierarchy Process, AHP was employed in this research to determine the preferences of practitioners on the issue of sustainable waste management. The AHP is a theory of measurement, originally devised by Saaty (1980) through pairwise comparisons and relies on the judgements of

practitioners or stakeholders to derive priority scales for factors of an issue or system (Saaty, 2008). 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 due to diversity of its stakeholders within the waste management system (Zahedi, 1986; Leung, 1998). The priority scales measure elements in relative terms. The comparisons are made using a scale of absolute judgements that represent how much one element dominates another with respect to a given attribute. AHP is further discussed in section 3.3.2.

Data was analyzed using AHP technique with Expert Choice software and non-parametric statistical analysis – Kruskal Wallis using Minitab 15. The survey data was processed to identify significance of aspects and factors by individual stakeholders while descriptive statistics was used to establish the overall significances. The Kruskal Wallis analysis was applied to test for differences between the significances selected across sectors and locations for the aspects and factors.

Taking time and resources into account, five locations were deemed appropriate to represent the geographic locations in Nigeria. Diversity of opinion and approach among practitioners is further achieved by the four groups of practitioners identified – Central government; local/state government; private and academic sector. Section 3.3.8 presents a detailed discussion of the participant categories.

1.4 RESULTS AND DISCUSSION OF LITERATURE AND QUESTIONNAIRE SURVEY

The result and discussion of Chapter four presents the findings generated from the structured questionnaire and literature survey administered to eighty-seven solid waste management practitioners. Sustainable development is proposed from the literature survey as a concept to base the appraisal of solid waste management schemes and practices. The subsequent breakdown of the concept into measurable units is also suggested from review of literature. The result of the structured questionnaire survey designed to quantify sustainability as a means of assessing solid waste management is shown. The findings include corroborating sustainability development (SD) as an appropriate concept for building solid waste management assessment tool and its breakdown. The data collected from practitioners was analyzed to show the overall significance apportioned to each aspect and factor that was employed to derive a sustainability function to appraise waste management strategies. In addition, the weightings assigned by the five regions and four sectors are presented and significant statistical differences found mainly across the regions has been illustrated.

1.5 CASE STUDY

In Chapter five, the solid waste management scheme in Kaduna metropolis was appraised using the assessment tool developed in a case study analysis to evaluate the applicability of the tool. Kaduna, the capital of Kaduna state, is one of the largest cities in northern Nigeria ranked as the fourth most populous city with a population of 1,563,300 (Sanusi, 2010). It is one of the most important political, industrial and economic centres in Nigeria (Ojo, 1995; Okunola *et al*., 2007). It has been selected amongst the cities for establishing integrated solid waste management instituted by federal government (Hussain, 2008; Olaniyan *et al*., 2009).

The system boundary is defined by household and commercial waste from Kaduna metropolis over a period of one year. The solid waste management processes assessed included temporary storage, collection, transport, treatment and final disposal (den Boer, den Boer & Jager, 2007; Bjorklund *et al.*, Cleary 2009). The data inventory analysis involved data collection and calculation procedures to quantify relevant inputs and outputs of the solid waste management scheme in Kaduna city where 0.5 kg per capita daily waste generation, was adopted (Dauda and Osita, 2003; Nabegu, 2010). Due to scarcity of reliable data, representative data from other waste management strategies similar to that of Kaduna metropolis are employed. Indicators were specified, scored, normalised and aggregated to generate an index. The indicators are derivatives of the factors specified in the solid waste management assessment tool. The data used was relatively available and practical to measure and record.

1.5.1 Case study methodology

The sustainability function (Equation one) of Section 4.3.1 was used to establish the index for Kaduna metropolis by applying data gathered from literature. Two indicators were specified for each factor and assigned a maximum score of 100 points each to maintain uniformity across assessment factors while ensuring all aspects are appraised. Maximum scores specified for particular indicators are generally based on studies carried out by international bodies mainly United Nations Environmental Program scoreboard specified for ASEAN region (UNEP, 2005). The scores determined for each indicator were inserted into the SI function and aggregated to derive the sustainability index for the case study. Generally, a normative orientation is adopted for awarding the scores with a defined threshold specified similar to the study of Lang et al. (2007)

The environmental indicators employed include particulate matter, methane (CH_4) emission, leachate quality, disposal rate, waste generation and material recovery. The administrative

indicators encompass quality of policy and its applicability under policy factor; created waste management agencies and their level of functionality within their jurisdiction under management factor; acceptance and awareness in the responsibility issue category and the resilience and maintainability of technologies used within the system. Social indicators assessed include health, satisfaction of users regarding the strategy in place, consistency of service, awareness and participation of all stakeholders and fairness of the strategy within this generation and between generations. The economic indicators are based on the wages available for waste management jobs and the total costs of waste management compared to what is generally charged by service providers.

1.6 SUSTAINABLE SOLID WASTE MANAGEMENT

Chapter six focuses on the solid waste management assessment tool developed and its applicability. The results obtained from the attempt at quantifying sustainable development with regards solid waste management using a questionnaire survey has established an equation based on four evaluative aspects and thirteen factors. Amongst the four aspects, administrative aspect was found to be the most significant aspect despite its absence as a generic principle of sustainable development in the past (McDougall et al., 2001; Chung and Lo, 2003).

The chapter also includes the differences in Importance recorded across the various sectors and regions although an overall function was determined. This is in addition to willingness of waste management practitioners to take part in the survey, the differences associated with mode of questionnaire delivery and effects of gender and ethnicity of researcher. The applicability of the assessment tool with regards to other situations or regions is also examined in addition to the Kaduna management strategy evaluated.

The next chapter, Chapter two, will cover the review of pertinent waste management literature with particular emphasis on Nigeria and the assessment methods applied to management strategies.

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will cover the aims of solid waste management and the strategies employed by developed and developing countries. It will encompass waste generation, use of waste hierarchy and the various options available for the treatment and disposal of waste. Literature on solid waste management in Nigeria will be reviewed with the aim of establishing the existing regulations, waste generation and composition, functional elements of the system, general awareness and attitude of stakeholders and facilities and technologies issues. The stakeholders within the strategy are also studied in addition to cost and funding issues.

General methods employed to assess solid waste management strategies are established from the survey of literature that illustrate the application of cost benefit analysis (CBA), lifecycle assessment and (LCA), and multi-criteria analysis as the main concepts on which assessment techniques are based. Sustainable development as another concept is also proposed from the existing literature. This encompasses the breakdown into measurable units in three stages – evaluative aspects, which subdivided into factors and finally broken down into indicators.

2.2 SOLID WASTE MANAGEMENT

“Waste management has evolved from the simple transportation of waste to landfills to complex systems, including waste prevention and waste recycling as well as several waste treatment and landfill technologies” (Salhofer *et al*., 2007 pg 610). This is in response to the increasing quantity and complexity of the composition of waste generation all over the world.

According to the United Nations consultative meeting in Tokyo, the main challenge regarding waste management has changed perspective to the manner in which discarded resources will be handled such that future generations are not deprived of some or all of its value (Chandak, 2010). This is a shift from the older view of ensuring minimum damage to public health and environment in the process of handling waste (Chandak, 2010).

“A current trend in developed countries is closing the loop, moving from the concept of ‘end-of-pipe’ waste management towards a more holistic resource management” (Wilson, 2007). While developed countries have achieved the first aim of waste management of providing protection to human beings and the environment and are battling resource conservation, the health and well-

being of humans still suffer from inadequate waste management systems in developing countries and the first objective still remains a main priority (Brunner and Fellner, 2007).

In the recent past, the inability of member countries in the European Union to decouple waste growth from economic growth has imposed economic and environmental cost on society and created a pressing need to increase levels of effective waste minimization and management (Fatta and Moll, 2003). The trend in the UK has been a decline in waste growth for the past two years with the waste quantities consistent in the five years prior to 2008 (DEFRA, 2010). However, the cessation of waste growth persists for reasons that remain elusive (Fell, 2010) and not clearly attributed to the sole efforts of waste minimization and management schemes.

Waste management is regarded as a public service and those who do not pay are not totally excluded from the service generally. This is because efficient collection and safe disposal of waste, at the minimum, are essential to public health and environmental protection (Cointreau-Levine, 1994).

2.2.1 Waste management hierarchy

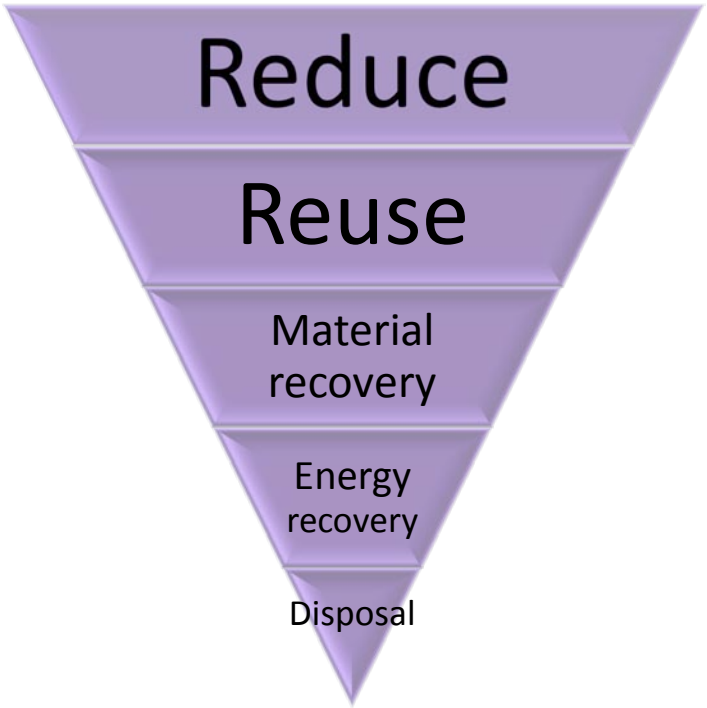


Figure 2.1 Waste management hierarchy (based on Brunner and Fellner, 2007; Finnveden *et al*., 2005; Lang et al., 2007)

With increasing complexity of solid waste generation and quality, many options of management have been specified guided by the waste hierarchy. An investigation by Finnveden *et al*. illustrated the general validity of the hierarchy as a rule of thumb (2000; 2005). However, the hierarchy has been reported to be inappropriate sometimes for situations where less than ten Euros is spent per capita per year to achieve the aims of solid waste management and in the event of unusual constraints (Seadon, 2006; Brunner and Fellner, 2007). The hierarchy consists of a preferred option of waste minimization, material recovery, energy recovery and landfill as the least preferred alternative as depicted in Figure 2.1 (Sakai *et al*., 1996; Lang *et al*., 2007).

2.2.2 Integrated solid waste management

Integrated solid waste management generally involves the use of the hierarchy in selecting the most preferred combination of options depending on waste generation and composition; demographic and socio-economic conditions of a region; environmental conditions and technical capacity (Najm *et al*., 2002; Gidarakos *et al*., 2006). The waste treatment options generally considered are recycling, incineration, landfilling, digestion and composting (Finnveden *et al*., 2000). For instance, a combination of material recovery and refuse-derived fuel were recommended for Columbia in the study of Zeng and Trauth (2005), while recycling, composting and incineration in different proportions were specified for Greece (Pilea) in 2002 by Koufodimos and Samaras. In Austria, the goals of waste management were found to be achieved more efficiently by thermal waste treatment (such as smelting-redox process and incineration) compared to mechanical-biological treatment or landfilling (Doberl *et al*., 2002).

2.2.3 Waste generation

Despite the deterioration of the urban environment of many developing countries from solid waste, the waste generated in developed countries is usually higher with that of UK per day estimated at 1.5 kg/capita, USA at 2.04 kg per capita and Denmark 2.2 kg per capita (EPA, 2008; EEA, 2010). Meanwhile, waste generated per person by developing countries are estimated at 0.5 kg/d in Ghana, 0.4 kg/d in Tanzania, 0.8 kg/d in Egypt and 0.6 kg/d in Mexico (Anomanyo, 2004; Kaseva and Mbuligwe, 2005; Badran and El-Haggar, 2006; Gomez *et al*., 2009). Current trends in the UK show a decline in the generation of waste (Leeds, 2010).

2.2.4 Responsibility of managing solid waste

Waste is generally managed by the public sector in most countries. It is managed by the ministry of environment in Singapore (Bai and Sutanto, 2002), municipal authority in Mumbai, India (Rathi, 2006) and by the local authorities in Kenya (Henry *et al*., 2006).The environmental protection authority (EPA) is responsible for solid waste in the United states while the city and county council in conjunction with Department for environment, food and rural affairs (DEFRA) are responsible in the UK (Leeds, 2010).

While developing countries are commonly associated with improper management of solid waste, improvements have been reported in some regions such as Iran; Lagos (Nigeria); Philippines, with a rise in recycling rate of 6% in 1997 to 25% in 2006 and Ghana (Moghadam *et al*., 2009; Wilson *et al*., 2009; Oresanya, 2010).

2.3 SOLID WASTE MANAGEMENT IN NIGERIA

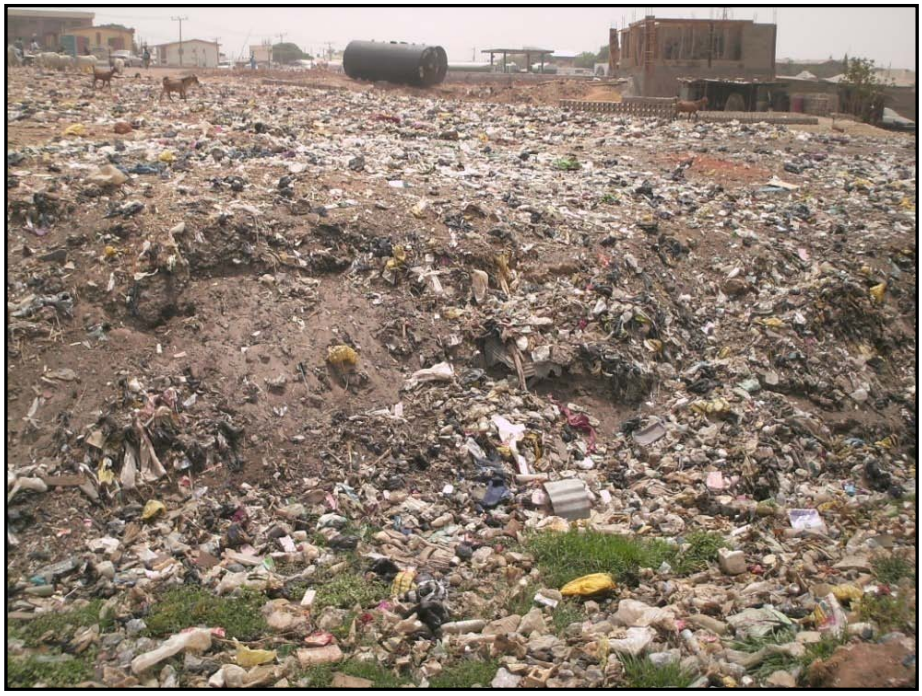
In Nigeria, there is a steady increase in waste variety and quantity due to population growth and industrialization (Imam *et al*., 2007), while the basic solid waste management system based on collection, transportation and disposal remains highly inefficient and ineffective (Ayotamuno and Gobo, 2004). This increase is especially steep in cities with an urban population growth rate of 5.5% against a general growth of 2.3% per annum in the nation (World Bank indicators, 2008; Imam *et al*., 2008). The inability of authorities to respond to the challenge of such waste generation has resulted in the deterioration of the urban centres that are characterized by heaps of uncollected refuse around cities as shown in Picture 2.1 (Ogu, 2000; Imam *et al*., 2007).

2.3.1 Nigeria

Nigeria is the most populous and the tenth largest country in Africa with a population of over a hundred and fifty million people across a landmass of 923,768 square kilometres (WDI, 2010). It is located in the Western part of the continent and lies between latitude of 10^{o} north and a longitude 8^{o} east.

The landmass of the country extends from the mangrove swamp at the farthest southern region to sudan savannah of the extreme northern region with the largest area (of over 40%) covered by the guinea savannah in the north west and north central (Ogunsote and Ogunsote, 2002; Adejuwon,

2006). The rest of the country is covered by fresh water swamp and high forest zones in the south, sahel and montane savannah zones in the north (Ogunsote and Ogunsote, 2002; Adejuwon, 2006).



Picture 2.1 Temporary storage at roadside, Kaduna by-pass (Source - original)

Temperatures are generally high throughout the year (between 28^{o} to 40^{o}), which results in faster decomposition of waste particularly in the presence of water (Hamoda *et al*., 1998; Sundberg and Johnsson, 2008). Low maximum temperatures are experienced in the coastal areas of the south while the highest and lowest average temperatures occur in the extreme Northern regions (Adejuwon, 2006). The country is characterised by wet and dry seasons from April to October and November to March respectively with February to early April hot and dry. A list of 374 ethnic groups was proposed by Otite (1990), while Hoffman suggested an inventory of 394, which has accorded the country a rich diversity in customs, religions and languages as well as conflicts (Mustapha, 2003).

Major cities include Kano, Lagos, Kaduna, Port-Harcourt, Ibadan, Maiduguri, Jos, Enugu and Calabar. Although the people are primarily rural dwellers, the country is urbanizing rapidly, which aggravates the problems of social services such as solid waste management (UNDB, 1998 cited in Imam *et al*., 2008; WDI, 2010). Furthermore, Nigeria has 60% of its population living below poverty line with an approximate labour force of 33% (Ogwueleka, 2009). This intensifies the incidences of

poorly planned areas within urban cities and the ensuing problems of managing waste (Imam *et al*., 2008).

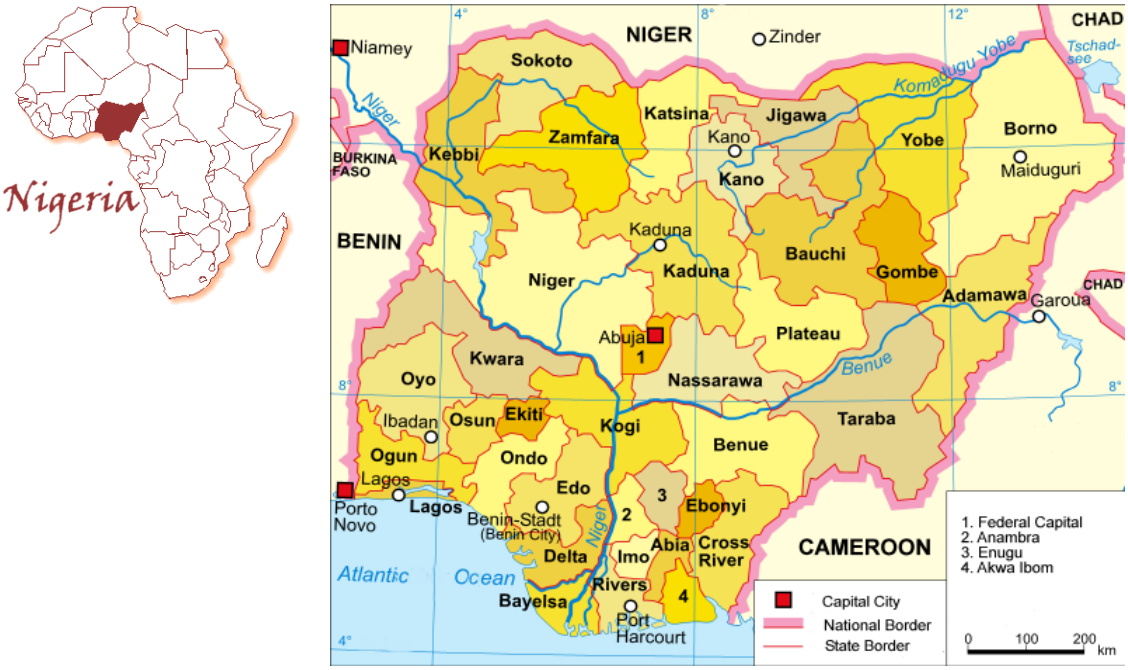


Figure 2.2 Africa – Nigeria

2.3.2 Waste management legislation

Nigeria operates a three tiers system of government made up of federal, state and local government with distinct functions accorded to each tier based on constitution (Afon, 2007).

2.3.2.1 Federal government

The milestone Federal legislation on environmental protection in Nigeria was the decree 58 of 1988, which established the Federal Environmental Protection Agency (FEPA) to control the growing problem of waste management and pollution in Nigeria (Walling *et al*., 2004; Imam *et al*., 2008).

Its role with respect to waste management was to (Onibukun, 1991):

- Study most reliable systems suitable for different waste types
- Specify waste disposal and treatment methods (encourage option at the top of hierarchy)
- Specify waste disposal sites that guarantee safety of water systems
- Set-up and enforce standards for adequate sanitary waste disposal facilities

- Establish monitoring programs (surveillance of disposal sites and control of leachate disposal)
- Establish monitoring stations for the control of leachate disposal from dumpsites into water systems

The legal frameworks for management of solid waste in Nigeria are (Okorodudu-Fubara, 1998; Onibukun, 1991):

- The National Protection Management of Solid and Hazardous Wastes Regulations (1991)
- The Pollution Abatement in Industries and Facilities generating Wastes Regulations (1991)
- The General Guidelines for Pollution Abatement in Industries (1991)

The Federal Ministry of Environment (FME) absorbed and took over from FEPA the function of administering and enforcing environmental laws in Nigeria in 1999 with implementation of these laws still fraught with problematic enforcement that has met with little success (Aluko and Oyebode, 2007; Adewole, 2009). In addition to the responsibilities of FEPA mentioned above, FME is responsible for making available to the public information on environment-related issues.

2.3.2.2 Local and state government

Although the state and local Government are empowered constitutionally to protect and improve the environment and safeguard the water, air and land, forest and wildlife of Nigeria (Aluko and Oyebode, 2007), solid waste management is the responsibility of the local government (Afon, 2007). The state government steps in to complement the efforts of the local government to achieve the goal of waste management in many cities especially state or regional capitals (Ogbonna *et al.*, 2007; Afon and Okewole, 2007). Up till the mid-eighties, the state government was responsible in Enugu and Kaduna while the responsibility shifted frequently between state and local government in Ibadan (Ogu, 2000).

All states have set up environmental agencies and laws to carry out this responsibility in addition to state ministries that have resulted in co-ordination being an issue (Adedibu, 1986). Kaduna has the Kaduna State Environmental Protection Authority (KEPA) as well as the State Ministry of Environment and Resources handling waste management in conjunction with the local governments. Collection and disposal is carried out by Borno State Environmental Protection Agency (BOSEPA) in Maiduguri (Dauda and Osita, 2003) while Lagos state waste management

authority (LAWMA) and Lagos state environmental protection agency (LASEPA) are battling with the massive quantities of waste in Lagos. Waste management is carried out by Abuja Environmental Protection Board (AEPB) in the Federal Capital Territory (FCT), Abuja (Imam *et al*., 2008) and Rivers State Environmental Sanitation Authority (RSESA) in Port Harcourt (Ogbonna *et al*., 2007). As a result of constant change of duties between organisations of the same region, the solid waste management scheme in Nigeria, not surprisingly, is characterized by a system fraught with lack of accountability (Walling *et al*., 2004). The situation is not far from the mid-eighties when lack of organizational structure and inadequate skilled manpower and equipment had the cities in the country with waste heaps and blocked drainages (Adedibu, 1986). Furthermore, some states formulate laws and edicts in conflict with the federal policy and hence increase the confusion of the management system (Ayotamuno and Gobo, 2004).

2.4 CURRENT SITUATION

2.4.1 Waste generation and composition

The importance of reliable information on both the quantity and composition of municipal solid waste for the effective planning of waste handling infrastructure has long been recognised. It shows the percentage of waste that can be recycled, reused, composted, and biologically stabilized (Dennison *et al*., 1996).

The total solid waste generation in Nigeria is rising steadily due to increase in population while scarcity of reliable data (Wilson *et al*., 2009) has made the per capita waste generation trend inconclusive. The estimate of waste generated per person in a day is 0.49 kg with households accounting for 90% of the urban waste (Solomon *et al*., 2009). The generation per person in cities at particular time intervals vary from 0.13 in Oyo (Afon and Okewole, 2007) 0.25 kg/day (Dauda and Osita, 2003) in Maiduguri to 0.47 kg in Makurdi (Sha'Ato *et al*., 2007) and at the top of the range Abuja with 0.57 average according to the waste audit report (2004). This is within the range of per person waste quantities in developing countries of 0.1 kg/day to 1.2 kg/day.

Solid waste generation is strongly influenced by time of year, traditions, personal income (AlJarrah and Abu Qdais, 2006; Imam *et al*., 2008), household size (Bandara, 2007) and environmental awareness and concern (Afroz 2010). A study by Afroz *et al*. (2010) found that individuals with higher income generated more waste than lower income people and respondents that were concerned about the environment generated less waste. In another study, the highest generation

of waste was recorded in December due to festivities in the southern city of Ogbomosho in Nigeria illustrating the influence of time of year and traditions (Afon, 2007). Larger households have been found to produce less waste than smaller households (Poll, 2004; Jones *et al*., 2008). A compilation of waste characteristics of some areas across the country is shown in Table 2.1.

Table 2.1 waste composition of some Nigeria cities

City	Abuja %	Maiduguri %	Oyo %	Kaduna %	Port Harcourt %	South west %
Category						
Organic waste	57.0	46	30.0	30.0	23.0	26.0
Plastics	18.0	12.7	19.0	20.0	11.0	6.0
Paper	11.0	5.7	14.0	15.0	15.0	16.0
Metal	5.0	10.7	6.0	15.0	9.0	11.0
Glass	4.0	5.8		5.0	9.0	7.0
Textile	2.0	4.0	4.4	5.0	6.0	8.0
Ashes, dust stones	-	13.0	10.3	-	1.0	3.0
Other	2.0	2.0	-	10.0	-	-
Garden waste	-	-	16.2	-	10.0	23
Cartons	-	-	-	-	16.0	-
Total	100	100	100	100	100	100
References	Waste audit report of 2004 in Imam *et al*., 2008	Olaniyan *et al*., 2009	Afon and Okewole, 2007	Anake *et al*. , 2009	Ogbonna *et al*., 2007	Sangodoyin and Ipadeola, 2000

The high organic content of waste in Nigeria is consistent with waste generated in other developing countries as illustrated in Table 2.1. The solid waste in Jordan has an organic content of 73% by weight (Abu Qdais, 2007), while Haiti and Palestine have 65% (Philippe and Culot, 2009; Al Khatib *et al*., 2010). Meanwhile, the organic content forms approximately 60% of the waste stream

in China (Zhang *et al*., 2010) and in Ghana (Fobil *et al*., 2010). The majority of non-degradable component of the waste is recyclable while various options exist for the degradable fraction such as composting and anaerobic digestion (Barton *et al*., 2008).

2.4.2 Temporary Storage

Waste is temporarily stored without separation at the point of generation within households or at communal disposal sites in urban cities in Nigeria. It is a key aspect of the management strategy as it determines to a large extent the efficiency and effectiveness of collection. Within and around households, waste is stored in various sizes of bins and bin bags by the more affluent population and in used baskets and buckets by the less affluent (Abdullahi *et al*., 2008). Unlike Abuja, the capital city in Nigeria, most environmental agencies have not made provision or specified collection containers (Imam *et al*., 2008).

More than 50% of the population in the cities use communal disposal sites as temporary storage. Waste is transferred from point of generation to these sites situated within each area by household members or contracted private collectors (Dauda and Osita, 2003). The communal disposal sites are open dumps characterized by uncontrolled emissions, presence of rodents and strong odour as depicted in Pictures 2.1 and 2.4.

2.4.3 Collection and transportation

Collection and transport involves both separate or co-mingled collection of solid waste and recyclables; and the transportation to processing and disposal facilities. Collection covers the emptying of bins or/and bin bags within or around the settlement area; and transport refers to the haulage of the collected waste to the disposal facility or treatment plant (Den Boer *et al*., 2007). Collection is carried out in various ways in different areas in Nigeria. This includes direct collection by the state or local government or indirect collection by appointed private contractors and/or informal waste managers for a fee. The various ways include:

- Kerbside collection – waste is collected from kerbs of households, where the households are responsible for bringing out the waste to the kerbsides on or before collection days (Abdullahi *et al*., 2008; Imam *et al*., 2008; Agunwamba, 1998).
- Receptacle or communal centre collection – The communal centre is usually an open space of shallow trench where waste is dumped directly on the ground or in a few cases

equipped with large bins into which the waste is discharged and eventually collected (Imam *et al*., 2008; Dauda and Osita 2003).

- Door-to- door or house-to-house pick up – The waste is kept temporarily within the properties concerned and generally collected from within the premises on a contract basis between householders and private organisations (Abdullahi *et al*., 2008; Sangodoyin 1993).

Waste is typically transported by lorries, tippers, loaders, trucks and tractors by formal sector (Dauda and Osita, 2003; Imam *et al*., 2008) and using hand pushed carts and wheel barrows by the informal sector.

Picture 2.2 Transport of waste with wheel barrow (Source - original)

Collection is generally irregular in most cities with communal dumps staying for months without evacuation in many instances (Dauda and Osita, 2003), while kerb side collection ranges from once a week to none at all (Abdulahi *et al*., 2008). The result of this ineffective and inefficient collection system is uncontrolled emissions of leachate and landfill gases that end up contaminating land and soil as well as polluting the air. This is in addition to nuisance of odour and destruction of landscape from waste heaps along streets and roads as can be seen in Picture 2.3.

Picture 2.3 Transport of waste with push cart and destroyed landscape (Source - original)

Picture 2.4 Transport of waste with truck from communal disposal site

2.4.4 Resource recovery and recycling

The composition of waste in Nigeria suggests a recyclable content of over 40% from Table 2.1 (pg 17) despite the high decomposable fraction. Recycling rate is estimated at 8-22% of total waste with paper contributing 5-15%, metal 10-40%, and plastics and glass 20-40% and 25-70% respectively (Wilson *et al*., 2009).

Resource recovery and recycling implemented in Nigeria is quite significant and compares well with many developed countries (Wilson *et al*., 2009). It is mainly carried out by the informal sector and data is generally scarce and difficult to generate (Wilson *et al*., 2009) as the sector is basically unregistered and unregulated and characterised with lack of planning, implementation and performance measurement and their appropriate documentation (Ogu, 2000).

The waste reduction and recycling activities carried out by the informal sector includes door-to door itinerant buying of paper, metals, glass and plastics directly from source (Wilson *et al*., 2009) and scavenging from waste containers, communal dumps and final disposal sites (Kofoworola, 2007). Itinerant buyers like waste pickers use waste items directly and/or sell to middle men or recycling companies (Wilson *et al*., 2009). The informal sector is a part of the private sector and will be discussed in Sections 2.2.6.2 and 2.2.6.3 of this chapter.

Organic fraction of waste, which would otherwise end up in the waste stream, is reduced by feeding animals and composting. A small percentage of the urban population keep pets or rear animals, which is more common in the rural areas. Urban farming, similar to other African cities such as Dares Salam, Tanzania, Daloa, Ivory Coast, Harare in Zimbabwe, and Accra in Ghana, is widespread in Nigerian cities (Asomani-Boateng and Haight, 2008). Furthermore, food waste is reduced by feeding the urban poor especially in the Northern cities that have the Almajiri system of schooling (Usman, 2008).

2.4.5 Waste treatment and disposal

The waste disposal option in Nigerian cities is predominantly open dumping followed closely by open burning (Osita and Dauda, 2003; Ogwueleka, 2009). The formal treatment of waste on the disposal site is usually open burning to reduce the quantity (Imam *et al*., 2008).

Waste collected by the private sector directly from households and evacuated from communal dumpsites is transported to final disposal sites where it is dumped in shallow pits or open grounds. This disposal route accounts for about 50% of the total generated waste. The rest of the waste

ends up in watercourses, drains, roadside spaces, underneath bridges, undeveloped properties, abandoned wells, pit latrines and borrows pits around cities (Sangodoyin, 1993; Ogu, 2000; Dauda and Osita 2003; Barton *et al*., 2008; Abdullahi *et al*., 2008; Imam *et al*., 2008) where it is left to rot, serving as a breeding ground for flies, rats, mosquitoes and other pests. Disposal sites are generally enclosed areas with (Agunwamba, 2003) or without site officials and guards and situated on the outskirts in some of the cities such as Kaduna and Abuja and within a short distance in many others. The sites are managed by a crew of five in some landfill sites to a non-existent crew in many open dumpsites all over the country except for waste depositors and visiting personnel (Agunwamba *et al*. 1998). The crew includes foremen, security men, record keepers, maintenance men and operators.

2.4.6 Private sector participation

The ineffectiveness of collection by the public sector in Nigeria, with uncollected waste of approximately 50%, has led to the birth of both formal and informal private sector participation (Kofoworola, 2007; Afon, 2007). Private sector participation is normally driven by the need to provide a solution for inadequate and/or overly expensive service provision (Cointreau-Levine, 1994; Ogu, 2000; Afon, 2007). The reason for adopting any one of the two options of formal or informal service usually depends on affordability and convenience (Afon, 2007).

2.4.6.1 Formal private sector

The formal private sector service provision is generally characterized by cleaner collection methods from source of waste generation and proper disposal to final dumpsites. They operate under four types of participation; contracting, concession, franchise and open competition (Cointreau-Levine, 1994; Ogu, 2000). The services associated with the formal sector include street sweeping, collection and transportation of waste from households and evacuation from communal dumps usually without recycling or other treatment options carried out (Ogu, 2000; Hussain, 2008; Nzeadibe, 2009).

- ***Contract***

Typically, a private firm is awarded a contract for a specific period by the government for service delivery and is paid under terms of the contract (Cointreau-Levine, 1994). In Kaduna presently, a number of private firms have been contracted to carry out these functions with the city zoned and allocated to each firm (Hussain, 2008).

- ***Concession***

This is usually a long-term contractual agreement where the private firm builds the facility for the service while utilizing government owned resource (such as land). Ownership of facility is transferred to the government in some cases after a specified period of private ownership and operation or remains with the private firm (Cointreau-Levine, 1994). Lagos state is in the process of finding out the viability of this type of private sector partnership for waste incineration with energy recovery with a private firm (Oresanya, 2010).

- ***Franchise***

Franchise involves a competitive selection process for private firms, who solely provide service(s) in a specified zone and usually recover cost of service directly from customers regulated by the government (Cointreau-Levine, 1994). The private firms pay license fee to cover the cost of government monitoring and deposits a performance bond with the government.

- ***Open competition***

Open competition entails customers making private arrangements with individual firms of their choice for service provision (Cointreau-Levine, 1994). A license is granted by the government to qualified companies who can compete and operate within a zone with any number of other firms. Costs are recovered from direct billing of customers.

2.4.6.2 Informal private sector

Similar to many developing countries, the activities associated with informal waste management sector in Nigeria are scavenging of reusable and recyclable items from temporary and final disposal sites, and collection and transportation from households to communal dumps (Wilson *et al*., 2006; Afon, 2007). Wilson et al. (2006) describes the sector as small-scale and labour-intensive, with low technology and pay; no documentation and largely unregulated and unregistered provision of waste management service. In addition, they do not pay taxes and are not licensed. The sector plays a significant but controversial role in the field of waste management (Elkan, 1988) as it is characterized with exploitation of participants, health and safety hazards while it serves a vital source of employment and income for the poor who have few alternatives for making a living (Nzeadibe, 2009). It is further driven by the market for recycled materials (Hayward and Gaskin, 2005; Nzeadibe, 2009). The venture is normally owned and operated by a single individual or a small group of individuals working in a loosely organised co-operative (Abdullahi *et al*., 2008; Wilson *et al*., 2009).

2.4.6.3 Informal sector entrepreneurs

Waste management informal sector in Nigeria comprise of itinerant buyers, waste pickers/collectors, middlemen and recycling companies depending on where and how material recovery takes place (Wilson *et al*., 2009).

- ***Itinerant buyers***

The itinerant buyers collect specific recyclable materials and/or organic wastes, door to door, from households and establishments, which they buy or barter with simple useable household items (Abdullahi *et al*., 2008). They tend to specialise in one or two kinds of materials such as plastics and bottles with materials collected used directly, sold to middlemen and recycling industries (Wilson *et al*., 2009). Their earnings per year is about ₦360, 000 (USD3058) (Wilson *et al*., 2009), which is higher than the minimum wage of ₦114, 000 (USD968) per annum. Equipments commonly used by itinerant buyers are push carts, wheel barrows and in a few cases motor vehicles (Imam *et al*., 2008).

- ***Scavengers***

Scavengers are found among formal waste collection crew who recover materials from vehicles while transporting waste to disposal site(s) (Wilson *et al*, 2009; Kofoworola, 2007). The most prominent ones however are those who scavenge for materials from bins, temporary and final dumpsites. Many of the informal waste collectors segregate the useful items from the waste and discard the residual waste at will. Generally, the materials collected are subjected to washing and drying and are used directly or sold for direct use while others are sold to middlemen andr recycling industries for processing (Kofoworola, 2007). The venture is formed of a single individual or few individuals who earn approximately ₦60, 000 (USD510) per annum (Wilson *et al*., 2009).

- ***Middlemen***

Middlemen are usually waste dealers who buy recovered materials from scavengers at the dumpsites or in their small shops and make about ₦500, 000 (USD4248) per year from these proceedings (Wilson *et al*., 2009; Kofoworola, 2007). The materials bought are further separated; sold directly to consumers or supplied to appropriate manufacturers (Kofoworola, 2007).

Policy makers and planners face a difficult dilemma due to widely differing opinions when dealing with the informal sector (Nwaka, 2005). Some stakeholders on one end of the spectrum believe the sector to be an obstacle to development of modern economy with its non-payment of tax and lack of respect for legal, social, health and quality standards (Nwaka, 2005). On the other end of the spectrum, the more realistic view adopted by more stakeholders is the sector remains a viable

source of much needed income, and provides a significant service of waste collection for a significant percent of the populace and resource recovery that would otherwise be absent in the urban cities of Nigeria (Ogu, 2000; Nwaka, 2005; Nzeadibe, 2009).

The conflicting positions of stakeholder have resulted in ambivalence and hostility of waste management officials towards the sector (Nwaka, 2005) and their activities are at best ignored. A means of supporting and regulating this sector is therefore a challenge to the policy and managers (Nzeadibe, 2009).

2.4.7 Awareness and Attitude

2.4.7.1 Awareness

The waste management service providers i.e. the local/state government are responsible for raising awareness on solid waste management issues. In Abuja, the AEPB are currently performing this task by promoting environmental clubs in schools engaged in formal education as well as through print and electronic media (Abdullahi *et al*., 2008). This is further enhanced by impacting knowledge via television specific to Abuja as indicated by Imam *et al*. (2008).

The main means of creating awareness in Nigerian cities focuses on organizing seminars, conferences, workshops and training sessions as suggested by practitioners in the course of the survey in this study. This is in addition to including environmental management as topics within established subjects such as integrated science and social studies in junior secondary schools where teachers are unprepared to achieve the desired outcome of instilling awareness and knowledge and end up giving it insignificant attention (Uhuo and Zavodska, 2010).

With a literacy rate of 68% and over 13% of children out of school at the junior secondary level (World Bank indicators, 2008), a percentage of the population has lost out on the environmental education while the method for the adult awareness programmes require more than basic literacy in understanding the message of waste management issues and options being delivered. Babayemi and Dauda (2009) in his report suggested a high awareness level of some aspects of solid waste management such as waste disposal options and waste management regulations with females showing a better understanding of issues than males. However, effective awareness alone cannot sustain a good environmental quality, which can only be achieved in conjunction with many other elements such as provision of facilities, equipment and capacity building that is lacking at present.

2.4.7.2 Attitude

Public awareness and attitude can affect all stages in the waste management process (Imam *et al*., 2008). This has an impact on household waste storage, waste segregation, recycling, collection frequency, littering and fly-tipping, willingness to pay for waste management services, and the level and type of opposition to waste treatment and disposal facilities.

People in Nigeria generally have a poor attitude to waste that is unsupportive of effective waste management (Agunwamba, 2003; Walling *et al*., 2004; Adewole, 2009). Most people perceive environmental quality as the sole responsibility of the government and the individual has only an unimportant role of disposing waste from their immediate surroundings (Adewole, 2009). Common occurrences in many over-populated cities are the throwing away of small items of waste from cars and by pedestrians onto the streets and the use of streets as toilets (Adewole, 2009). Creation of illegal communal dumps for convenience of residents is also a widespread practice. According to Imam *et al*. (2008) transporting household waste is normally regarded as the duty of children and people who handle the waste are often regarded as dirty and poor.

In addition to negative attitude, lack of facilities also prompts improper disposal of waste (Dauda and Osita, 2003). A protective orientation and custodial attitude toward the environment has been identified among the critically missing components in current waste management initiatives in urban Nigeria (Nwako 1994; Ogu 2000).

2.4.8 Cost, Funding and facilities

2.4.8.1 Cost and Funding

Collection and transportation of waste is labour and capital intensive and accounts for between 70-80% of total cost of waste management in Nigeria (UNDP, 1998). In general, solid waste management costs are covered indirectly through taxes, permits and rates. The lack of capacity within local authorities for billing and revenue generation generally results in a very low portion of revenue being collected and thus a low financial base to cover salaries and running costs associated with solid waste management (Ogawa, 1996). Also, many households are not used to paying for waste management services and are reluctant to pay. Waste management in Nigeria is heavily subsidised by the three tiers of government, especially the state government, with a little cost recovered from a few private homes and commercial establishments (Afon, 2007).

2.4.9 Technologies – Machinery, equipment and skilled labour

Irregular collection and transportation of waste is mainly attributed to frequent breakdown of machinery and inadequate facilities (Dauda and Osita, 2003; Imam *et al*., 2008). Studies by Barton *et al*. (2008), Adewole (2009) suggest the cause to be lack of technical skill, poor maintenance practices, lack of spare parts and generally inappropriate choice of technologies by the authorities. Efficient collection depends, to a large extent; on proper selection of vehicles and technologies that need to take account certain conditions as reported by Dauda and Osita (2003), Kofoworola (2007), Imam *et al*. (2008) and Adewole (2009). The factors include:

2.4.9.1 Waste type and composition

The types of materials that compose the majority of the waste in Nigeria like other developing countries is a higher proportion of organics and considerably less plastics compared to industrialized countries (Cointreau, 1982 in Baud, 2004). The large percentage of organics in the waste makes it denser with moisture and smaller particle size. This makes certain vehicles and collection equipment less effective and prone to break down because of the heavier, wetter and more corrosive quality of their burden (Cointreau, 1982 in Baud, 2004).

2.4.9.2 Road conditions

The cities in Nigeria are characterized by many unplanned, haphazardly constructed, sprawling slums with narrow and uneven roads that are inaccessible to collection vehicles (Daskalopoulos *et al*., 1998 in Walling *et al*., 2004; Nwaka, 2005). Also, many paved roads are inundated with pot holes, which contribute to the breakdown and high maintenance rates of collection vehicles.

2.4.9.3 Cost

Cost of maintenance and purchase of vehicles is above the waste management financial capabilities of many waste management organizations in Nigeria (Walling *et al*., 2004).

2.4.9.4 Availability of spare parts and technical skills

Indigenous equipments are used by the informal sector that hardly requires fuelling. However, the formal sector uses bigger collection vehicles such as lorries and tippers that require external technical assistance and spare parts for maintenance (Imam *et al*., 2008).

2.4.9.5 Servicing requirements and haulage distances

Servicing requirements and haulage distances – haulage distances are city specific and servicing requirements depend on the choices made by specific waste management organizations.

2.5 SUSTAINABILITY IN SOLID WASTE MANAGEMENT

Modern waste management presents a high level of complexity that requires many aspects to be considered for a suitable solution that encapsulates both the current state of the environment as well as its potential to provide support for future generations (Jha and Murthy, 2002). What is apparent is a need to develop a comprehensive assessment method that enables identification of the present waste management status while giving stakeholders an insight into the problem and a platform for discourse.

Researchers of various disciplines are developing sustainability principles and strategies pertinent to their fields (Redclift, 1994). In waste management, these principles should aim at viewing the full range of activities of the system such as temporary storage and collection, while considering all stakeholders (Tammemagi, 1999; Chung and lo 2003; van de Klundert, 1996).

Although it has been suggested that the generally wide acceptance of sustainable development concept is due to its vagueness with varying degrees of interpretations (Bosshard, 2000; Lang *et al*., 2007), there is a strong agreement across the environmental and waste management field on the basic principles and elements of the concept as well as many of the criteria used in characterising or measuring the system.

The term sustainable waste management emphasizes a shift from waste disposal to other waste management options that includes energy and material recovery as well as waste reduction and reuse in addition to the aim of decoupling increase in waste generation from economic growth, a natural progression in many nations (Chung and Lo, 2003; EEA, 2005; Desmond, 2006). It includes having a strategy in place that is appropriate to the local conditions and has a balance between technical, environmental, social, economic, financial, administrative and political aspects, and is capable of maintaining itself over time without exhausting the resources it needs (van de Klundert, 2000; Joseph, 2006).

To evaluate waste management systems sustainably, the issue of measure of sustainable development arises - this requires transparent and reliable measurement element that must be agreed upon by stakeholders (Murthy, 2002; Joseph, 2006; Lang *et al*., 2007). While the generic principles of sustainable development consist of social, environmental and economic aspects, the administrative aspect has been evaluated in many studies involving waste management (van de Klundert, 1996; van de Klundert and Anschutz 2000; Chung and Lo, 2002 Hayward and Gaskin 2005; Desmond 2006; Klang *et al*., 2008). These aspects cover the range of issues associated with

the management of solid waste and taken together, predict or influence the sustainability of the entire system (Ashley *et al*., 2005).

2.5.1 Environmental sustainability

The objectives for environmental sustainability are summarized as rational resource consumption that can be achieved by conservation of the resources during and by the waste management processes and reduction of environmental pollution, which protects human health and the environment (Chung and Lo, 2003; den Boer *et al*., 2007; Hung *et al*., 2007; Roussat *et al*., 2009). From its source point to disposal and handling process, waste should be channelled to avoid pollution and becoming a nuisance (such as odour and noise) in addition to the strategy's avoidance of damage to the biosphere and any ecosystem presently and in the future (Imran *et al.*, 2008).

2.5.1.1 Air and water quality

Dispersion of dangerous substances into the environment in the form of emissions into the air, soil and water are important issues to be considered under the environmental aspect of a strategy.

Landfill gas is a naturally occurring by-product of decomposing organic waste and consists mainly of CH_4 and CO_2, which are significant greenhouse gases as well as SOx and NOx in small amounts (Goosens, 1996; Chugh *et al*., 1999). The risk of fire explosion and hazards that may result from CH_4 coming into contact with O_2 are other negative impacts (especially on dilute and disperse landfill sites) (Goosens, 1996).

This is in addition to leachate, a highly toxic liquid that contaminates ground and surface water, generated from decomposition of waste in the presence of water or liquid (Fatta *et al*., 2002; Aluko *et al*., 2003; Al-Jarrah and Abu Qdais, 2006). Critical to the control and management of environmental problems of disposal is an understanding of the leachate and gas composition and quality (Westlake, 1995) that gives an insight into the choice for an appropriate and effective treatment approach. Organic and inorganic pressures, heavy metals and pathogens are the common parameters used in characterizing the quality of leachate (Ikem *et al*., 2002; Aluko *et al*., 2003).

To assess a management scheme, impact measure is deemed the most important kind of environmental measure, concerned with ultimate effect of emissions and action on the biosphere and is the foundation of most environmental measurement systems (Bennet *et al*., 1999).

2.5.1.2 Resource Conservation

The wellbeing, quality-of-life and the health of ecosystems are becoming increasingly compromised by pollution and over-exploitation of resources due (in part) to world population and partial economic growth, mainly attributed to the enormous global consumer appetite (Fatta and Moll, 2003; Kally and Zhechkov, 2010). A management strategy that encourages the implementation of the waste management hierarchy with emphasis on waste minimization followed by recycling reduces the load on the environment by conserving the earth's dwindling resources while addressing the growing mountains of waste. Renewable and non-renewable resources are conserved in addition to savings in waste handling and processing costs (Fatta and Moll, 2003). Performance of a management scheme for this component is normally based on recycling rates which indicates the amount of resource conserved and waste diverted from the waste stream and final disposal (van de Klundert *et al*., 2001).

2.5.2 Administrative sustainability

The concept of sustainable waste management cannot be separated from good governance. This refers to the process of administration, and more broadly, to the ways in which society manages its collective interest such as waste (Imran *et al*, 2008). The primary responsibility of waste management remain with the public sector, normally the municipal government and is ultimately accountable for the functioning of the system, no matter the number of participants employed to perform tasks in the system (van de Klundert and Lardinois, 1995).

The administrative aspect encompasses policy, which provide guidelines for management, and management that decides the running of every aspect of the system within the policy framework (Walmsley *et al*., 2002). It also includes research and training that provide knowledge on further management options to take, and responsibility issues, which determines the role of all stakeholders (Walmsley *et al*., 2002). Also of great importance are the technologies used to provide the waste management service (van de Klundert, 2000).

2.5.2.1 Policy

Policy is among the important elements of proper management of waste (Rushbrook and Finnecy 1988)**.** A consistent and supportive legislation forms an indispensable foundation to waste management systems (van de Klundert and Lardinois, 1995). Stringent and detailed regulations and enforcement mechanisms to govern the systems in terms of kinds of materials to be thrown

away by waste generators, type of storage containers, kind of equipment used in collecting and disposing waste are some important factors that contribute to the success of waste management schemes as well as ensure adequate performance of private enterprises (van de Klundert and Lardinois, 1995).

The government has the responsibility of providing a waste management system appropriate to local circumstances and international treaties by bringing together its many different but related facets (Rushbrook and Finnecy, 1988). One of the main features of the system structure is a national policy to achieve the objectives of waste management. Once the policy is developed, a group of issues must be addressed to ensure the objectives are met and legislation for ensuring policy is implemented must be produced. In addition, the policy on waste management must take into consideration and integrate other existing policies relating to many different aspects, such as the policies for air, fresh water, and marine pollution (Rushbrook and Finnecy, 1988).

2.5.2.2 Management

Sustainable waste management should be driven by appropriate policies and regulations that can be carried out continuously in the short and long term (Chung and Lo, 2003). Adequate arrangement must be in place for collection, treatment and disposal of generated solid wastes. The arrangement will include provision of waste treatment, recovery and disposal sites; equipment to treat, recover and dispose the wastes; and trained personnel to carry out those duties.

The presence of an infrastructure to administer, regulate, monitor performance and enforce the law must be guaranteed in addition to an organization/department for future planning. The vital roles of authorities in charge of waste management comprise (Rushbrook and Finnecy, 1988);

- Identifying the need to manage waste and identification of any associated problems
- Assessment of its magnitude and importance, which involves actions such as data collection and analysis
- Study of waste management and related activities such as illnesses due to solid waste and employment creation
- Developing policy to deal or counter the problem(s)
- Assessment of resources to implement policy
- Production of legislation to implement policy, establishment of regulatory authorities, allocation of resources and training staff

- Implementation and enforcement of legislation, provision of guidance to all stakeholders and prosecution of offenders
- Monitoring to measure achievements against policy objectives
- Stimulation and support of research into problems
- Forward planning, continuous review of methods to achieve the overall objectives and their appropriateness to the developing situation and provision of new facilities.

2.5.2.3 Responsibility issues

A broadened understanding of components of integrated waste management systems and participant roles is essential for effective schemes. The shift of waste management from total reliance on disposal has led to rapid change in institutional relationships leading to some confusion over roles, responsibilities and relationships (Davoudi, 2000). These changes are further brought about by a change in policies and international standards of waste management.

Regulatory issues exist on different levels; ranging from households, communities to city levels where each level has its responsibilities as individual; group; organization and society (Lang *et al*., n.d; Hayward and Gaskin, 2005). At the household level, families can contribute physically to the system through waste reduction, source separation and composting activities. On a social level, parents can instil these concepts in their children so the future generations can understand their benefits and continue to operate and improve the system (Rushbrook and Finnecy, 1988; Hayward and Gaskin, 2005).

At the community level, collection, recycling and composting instituted can involve the informal private, formal private and public sectors to operate the various elements of the system. The local Government and Non-Governmental Organisations can work to institute programmes that will encourage these activities and educate society of their benefits (Hayward and Gaskin, 2005; Joseph, 2006). The state or municipal Government oversees the entire system by putting regulations in place to control the system and protect public interests (Hayward and Gaskin, 2005; Joseph, 2006).

2.5.2.4 Technical issues

Sustainable technical options suggest the application of the most viable combination of waste management facilities and equipment with the lowest possible risks to human health and environment in the long and short term (Eduardo, n.d). They should also be adaptable to the range of projected changes for economic, social and natural environments (Baetz, 1990). Viability of

technologies also encompasses the use and improvement of indigenous equipment, methods and personnel (van de Klundert and Lardinois , 1995; Rushbrook and Finnecy 1988). An assessment of the equipments, facilities and manpower available within a scheme suggests a suitable means of evaluation of institutional principle of sustainable waste management.

2.5.3 Social sustainability

A priority of the waste management as well as social sustainable is to ensure human health and well-being in this generation and generations to come. It also includes involving society in waste management processes by engaging members of the society to work together in achieving short and long term goals (Imran *et al*., 2008).

2.5.3.1 Health

A major cause of disease is improper management of solid waste in many developing countries with associated negative impact on the economy due to lost workdays, cost of treatment and mitigating activities (Joseph, 2006). These health effects include spread of diseases such as typhoid fever and lasso fever by flies and rodents; and malaria from mosquitoes that use waste heaps and blocked drainages as breeding grounds (Joseph, 2006). This is in addition to health issues resulting from direct contact with waste such as injuries, infected cuts, respiratory and skin infections (Rogers, 2002; Joseph, 2006). However, evidence from other studies indicates that the link between people working with waste having more infections is inconclusive.

Health effects are investigated in two main ways according to DEFRA (2004):

- Epidemiological studies – these are studies of the distribution (or pattern) and determinants (or causes) of disease in human populations.
- Emissions based studies – which measure emissions being released into the environment from one or more sources. Based on this, human exposures to emitted substances can be estimated, and the risks to human health can be assessed.

Emission based studies are undertaken because the health impacts arise mainly from exposure to toxic chemicals through air, water and soil media; exposure to infection and biological contaminants; stress related to odour, noise, vermin and visual amenity; risk of fires, explosions, and subsidence; spills, accidents and transport emissions (Caincross and Feachem, 1993). While the sophistication of the waste hierarchy is driven by environmental awareness, protection of

public health provides the underlying motivation for waste management practices and is satisfied through the collection and sanitary disposal of the wastes (Hayward and Gaskin, 2005).

The most vulnerable workers within the waste system are usually women and children working as waste pickers or salvagers from waste dumps, who are poor, live in very poor conditions, and suffer stigmatization and exploitation because handling waste materials is usually disdained by society at large (Hayward and Gaskin, 2005).

2.5.3.2 Social acceptability and Stakeholder involvement

Any moves to introduce sustainable systems can only be made in conjunction with the system users — the public, who must be involved in the formulation of any new practices which require a change in lifestyle and well-being (Ashley *et al*. 1999).

Positive behavioural change is a basic requirement for effective waste management in both developing and developing nations, affluent or poor, where public understanding, awareness, consensus, acceptance and participation are essential for an effective waste management strategy (Petts, 2000). This is especially so when embarking upon more sustainable options of reuse, repair and composting, which are highly waste generator dependent (Wilson *et al*., 2007). An indication of acceptance is the amount of waste reduction and other good practices achieved in a given system or a direct analysis based on measuring level of stakeholder involvement.

2.5.3.3 Social equity

A sustainable system should ensure equal opportunities in terms of employment, uniform collection method or impact and a well distributed situating of waste disposal facilities without bias to any social, religious, ethnic or political group (Eduardo n.d; van de Klundert and Lardinois, 1995).

Also, the long-term stability and viability of the system is endangered if the costs and benefits of the system are not fairly allocated between the present and the future generation (Lang *et al*., 2007). It is also essential that the developments of the waste management scheme should be sustainable such that the goals are achieved in a manner that does not impair the well-being of current and future generations (Brunner and Fellner, 2007).

2.5.3.4 Service quality

The quality of service can be evaluated based on the state of the environment on one hand and the perception of stakeholders on the other.

The percentage of population with access to waste management services decides to a large extent the state of the environment as those without services will succumb to inappropriate disposal means (Ogu, 2000). Despite the state of the environment, personal opinions will differ as to the effectiveness of the service available to the public. For instance, there was general user satisfaction associated with informal sector collection service in Lagos (Afon, 2007) at a time when the collectors were notorious for disposing waste at random on streets and public spaces as well as communal dumps that have been apparently outlawed since the 1980's (Hussain, 2008).

2.5.4 Economic and financial sustainability

Economically sustainable waste management takes into account all external costs into the total cost for waste management which includes pollution prevention cost and social cost in the short and long term (Imran *et al*., 2008).

2.5.4.1 Cost

Full cost analysis is essential to gain a clear picture of true costs and revenue to assess the sustainability of the system as well as establish a fair and realistic fund recovery system for services rendered (van de Klundert and Lardinois, 1995). Cost should be based on clear understanding of current circumstances and implications for the future generations and considering all stakeholders, waste management processes and components (van de Klundert and Lardinois, 1995).

Economic sustainability implies the least expensive waste management that ensures adequate revenue for economically sound and continuous operation and coverage of all aftercare expenses for a period stipulated by the law (Den Boer *et al*., 2007). It therefore implies that the cost of managing waste must be equal or less than the income generated for it to be sustainable. The economic aspect will also examine the extent to which the economic burden is distributed equitably among neighbourhoods and citizens, measured by cost of waste management per person per income and cost of waste management per person as a percentage of minimum wages. Subsidies are to be taken into consideration in the case of external financial assistance to waste managers (Den Boer *et al*., 2007). However, the continuity of assistance must be evaluated.

2.5.4.2 Employment

Sustainable waste management seeks to improve employment opportunities and reduce poverty for the people working with waste (Baud, 2001). It usually covers an integrated approach using the

most appropriate waste management options in the hierarchy based on unique conditions (i.e context specific). These options result into income and employment generation to the community with varying levels of knowledge and expertise while reducing and diverting waste quantities going to final disposal sites (Diaz *et al*., 1996, Kaseva *et al*., 2002; Hayward and Gaskin, 2005).

2.6 SOLID WASTE MANAGEMENT ASSESSMENT

Solid waste management assessment is undertaken to measure performance of the strategy in place for different purposes but with the main aim of improving existing strategy and practices. Some of the reasons are identifying a requirement for different facilities and new investments; ascertaining a need for combining or dividing the agencies or department(s) responsible for service provision; information dissemination between stakeholder groups and to provide a platform for obtaining grants, loans and funds from government and international bodies (Anschutz, 2004). Various methodologies have been used to evaluate waste management schemes where single, dual and multiple components have been modelled and evaluated. The methodologies used are generally based on three models – cost benefit analysis (CBA), life cycle assessment (LCA) and multi-criteria analysis (MCA) (Morrissey and Browne, 2004) discussed in Sections 2.3.1 to 2.3.3.

2.6.1 Cost benefit ANALYSIS (CBA)

Assessments founded on CBA are clear, concise and presented in a common measurement with all aspects of solid waste management estimated in monetary terms. This includes both environmental and social impacts, if included, that raises ethical issues as well as a high degree of uncertainty and inconsistencies (Morrissey and Browne, 2004; Pickin, 2008). According to Soderbaum, (2006), CBA insists only certain ways of viewing a problem are valid (that is in monetary terms), which is in conflict with environmental issues where all multi-disciplinary stakeholders and a wide range of issues must be taken into account. Although it enables decision makers to view the efficiency of resource use fairly simply, fluctuation in prices may affect judgements made over periods of time (Soderbaum, 2006).

Despite the uncertainties and inconsistencies of the CBA approach (Morrissey and Browne, 2004), its convenience ensures its application in many fields (Hanley and splash, 1994). Some of its applications include assessing waste management scenarios in the UK by Jamasb and Nepal in

2010; analysing construction and demolition waste by Yuan *et al*., (2010) and appraising open dump and sanitary landfill (Canto, 2010).

2.6.2 Life cycle assessment (LCA)

Life cycle assessment approach provides a general overview of the functional elements of the solid waste management system in terms of the environmental impacts (Morrissey and Browne, 2004). LCA studies the environmental aspects and potential impacts throughout a product's (or service function's) life; from raw material acquisition through production, use and disposal, (Moberg *et al*., 2005). Its main limitation is the disregard for other significant aspects of a system when applied in isolation, although it is holistic in evaluating all functional elements of the system. The inclusion of other aspects in some studies is confined to health impacts and policy implications of environmental issues (Finndeven *et al*., 2005; Moberg *et al*., 2005). The life cycle assessment is an internationally standardized method that is able to account for upstream and downstream inputs and emissions related to the life cycle of a product or a service. It was developed from chemical engineering principles and energy analysis and is generally considered an effective environmental management tool, which can be used to obtain an objective quantification of all the environmental impacts related with different solid waste management scenarios (Arena *et al*., 2003; Moberg *et al*., 2005; Ozeler *et al*., 2006).

Establishing the boundary of the system and subsequently defining the functional elements may pose some difficulty (Morrissey and Browne, 2004). Cleary (2009) in his evaluation of applications of LCA of solid waste management systems reported both consistencies and inconsistencies in the boundaries adopted, emissions incorporated and inclusion of capital equipment within the system. Furthermore, a lack of transparency in terms of methodological assumptions adopted by some researchers makes meaningful use of results difficult (Morrissey and Browne, 2004). However, the impact assessment stage of category selection, indicators and models selection, classification, characterisation and weighting are approaches similar to those employed in this study. The impact categories of LCA studies tend to be environmental impacts (Moberg et al., 2005) generally excluding social, economic and administrative aspects.

There is a wide range of LCA applications in establishing environmental impact of solid waste singly and in conjunction with other evaluation techniques (Rodriguez-Iglesias *et al*., 2003; [2]Finndeven and Nillson, 2005; Emery *et al*., 2007; Den Boer *et al*., 2007; Banar *et al*., 2009; Hong *et al*., 2010). It has been applied to determine the most feasible solid waste management method

by testing assessing the impact of various scenarios within a specified context (Ozeler *et al*., 2005; [5]Bjorklund and Finnveden, 2005; Zaman, 2010). Focus on the energy use and the emissions of the system(s) being appraised are evident in the studies of Morselli *et al*., 2005; [1]Moberg *et al*., 2005; [3]Finnveden *et al*., 2005)

2.6.3 Multi-criteria analysis (MCA)

MCA approaches are used to identify a single most preferred option; to rank options and to distinguish between acceptable and unacceptable possibilities in decision making while taking into account often conflicting criteria in a multi-dimensional way usually involving a wide range of multi-disciplinary stakeholders (Morrissey and Browne, 2004; Dodgson, 2009). In the process of carrying out the MCA, stakeholders become well acquainted with the issues and alternative solutions from different perspectives (Dodgson, 2009). It generally involves identifying several alternatives such as the combination of waste treatment options, and a list of criteria relevant to the issue (Morrissey and Browne, 2004; Tudela, 2006) that must be measurable to assess objective performance (Dodgson, 2009).

There are many MCA techniques such as the multi-attribute methods, the outranking procedures and the Analytic Hierarchy Process (Tudela *et al*., 2006; Dodgson, 2009) with a huge range of applications across many fields' especially environmental science and technology. Studies in the area of solid waste management include selection of management activities by Vaillancourt and Waaub (2002), facility location carried out by Lahdelma *et al*. (2002), recycling of waste by Gomes *et al*., 2008 and strategy selection of Roussat *et al*. (2009). The choice of MCA technique depends on awarded time scale, availability of relevant data, analytical skills of facilitator(s) and stakeholders and administrative culture/requirements (Dodgson, 2009).

The MCA as a methodology for tackling waste management problems appears to have many advantages. Apart from waste management involving a wide range of stakeholders, a large amount of quantitative as well as qualitative data must be processed together that can relatively easily be incorporated by MCA approach (Morrissey and Browne, 2004). Furthermore, it ensures representation of stakeholders with conflicting objectives as their preferences are taken into account in the process.

Unlike CBA it cannot show one action adds more value than it detracts in a situation. However, it provides an audit trail as open and explicit scores and weights are used in addition to open and

explicit criteria that are developed according to established techniques (Morrisey and Browne, 2004; Dodgson, 2009). 'There is a need for personal judgement and experience' (Morrissey and Browne, 2004 pg 302) that can be regarded as a limitation; however it can be argued that experience gives credibility to the exercise. Although it can become cumbersome (Beynon *et al*., 2000), MCA techniques offer a level of flexibility and detail that other approaches lack by incorporating various dimensions of an issue (Morrissey and Browne, 2004).

2.7 RESEARCH RATIONAL

Solid waste management in Nigeria has received considerable attention mostly in the areas of waste quantity and quality (Adedibu 1984; Sridhar *et al*., 1984; Afon 2007; Afon and Okewole, 2007; Sha'Ato *et al*., 2007); a few on regulations and governance (Adedibu 1986; Oyelola and Babade 2008; Kalu *et al*., 2009; Nzeadibe 2010) and especially on the status of the existing strategy (Agunwamba *et al*., 1998; Dauda and Osita, 2003, Izugbara and Umoh, 2004; Ayotamuno and Gobo, 2004; Ajibade, 2007; Ajani 2008; Babayemi and Dauda, 2009); state of the environment (Akeredolu 1988; Olukesusi, 1988; Bammeke and Sridhar, 1989; Baumbach, 1995; Aluko *et al*., 2003; Olaniyan 2007; Anake 2009) and a few regarding perception and awareness (Babayemi and Dauda, 2009; Longe *et al*., 2009). While work on systematic assessment of current strategy is non-existent, Abdullahi *et al*. proposed an appropriate management strategy that included all stakeholder categories operating in the existing scheme including the highly controversial informal sector (2008). Where waste management is assessed, the approach employed is usually not based on any particular methodology and usually qualitative. Although most management of waste strategies including that of Nigeria ascribe to sustainability, assessing progress towards this goal commonly carried out by use of indicators varies widely with no consistent tool or framework for application (Desmond, 2006).

Some assessment tools have been proposed in the Europe and Asia that have incorporated the desired social and administrative aspects and integrating various stakeholder groups and levels (Desmond, 2006) with some having a bias towards a particular issue (van de Klundert and Anschutz, 2000) and therefore not considering the whole system. There is also a general disregard of social issues by standardised methods employed to assess solid waste management systems, such as environmental impact assessment and life-cycle assessment, which is not oriented towards the first aim of waste management of ensuring human health is protected (Brunner and Fellner, 2007). While this disregard is minor in affluent countries where the protection of human

health directly associated with solid waste has been achieved, it is a major issue in developing countries (Brunner and Fellner, 2007).

This study is an attempt to develop a solid waste management assessment tool for Nigeria and similar countries in response to the demand for reliable, coordinated and understandable information for all sector groups including the general public by adopting the concept of sustainable development in conjunction with MCA technique. The information required is to strengthen ability of appropriate stakeholders to monitor and evaluate trends and conditions of waste issues and increase accountability of the sector. The following chapter, Section Three, details the scope of the study and the strategy adopted in the attempt to achieve the aims and objectives of the research.

3.0 SCOPE OF STUDY

3.1 AIMS AND OBJECTIVES OF RESEARCH

The research described in this study was designed to analyse waste management by quantifying sustainability.

3.1.1 Aims

The work was carried out to accomplish three main aims:

- To establish the current situation of waste management in Nigeria
- Identify a means of assessing solid waste management in countries such as Nigeria
- Establish an index to assess the sustainability of the existing waste management scheme and evaluate applicability of the assessment model developed

3.1.2 Objectives

The strategy adopted to realize the primary aims of the study consisted of:

- Literature review to establish current situation of waste management in Nigeria
- Development of assessment tool by
  - review of literature on assessment methodologies
  - data collection and analysis of stakeholders opinions on waste management issues
- Evaluating the applicability of the assessment tool by identifying indicators to develop an index for a particular waste management scheme in Nigeria
- Recommendations and conclusions

3.2 INTRODUCTION

This chapter covers the strategy adopted to achieve the aims of this study, which primarily involved a structured questionnaire survey administered to solid waste management practitioners across Nigeria over a period of eleven months. Relevant literature on waste management was reviewed to appraise assessment methods and the current state of solid waste management particularly in Nigeria, which identified sustainable development SD as a suitable concept to build an assessment tool. The main aim of the survey was to corroborate the suitability of the concept of sustainable development for evaluating solid waste management schemes and its proposed

breakdown and to illustrate the varying significances of the broken down components in relation to one another.

The structured questionnaire survey adopted analytic hierarchy process (AHP) as the research instrument to collect data from waste management practitioners. It was employed to determine the preference of practitioners on the various aspects and factors that make up sustainable waste management. Similar to other multi-criteria analysis techniques, AHP takes into account the complexity of different aspects and often conflicting opinions due to diversity of stakeholders found within the waste management system (Dodgson *et al*., 2009).

A total of 87 practitioners grouped into four work sectors and five geographic regions were surveyed in Nigeria to represent the various stakeholder groups and take account of the cultural and geographical diversity of Nigeria. Prior to the main survey, a pilot survey was carried out ovr ten months to try out the instrument of data collection; check accessibility of respondents; gauge suitability of respondents and evaluate competency of questionnaire while measuring survey time and clarity of questions (Oppenheim, 1992; Potts, 2001). It involved twenty postal questionnaires with 75% response rate and six interviews in Nigeria and UK.

Data was analyzed using AHP technique with Expert Choice software and non parametric statistical analysis – Kruskal Wallis using Minitab 15. The survey data was processed to identify significance of aspects and factors by individual stakeholders while the Kruskal Wallis analysis was applied to test for differences between sectors and locations.

3.3 RESEARCH STRATEGY

Research strategy is a basic plan to conduct a study that makes it possible and suitable to draw more general conclusions from (Oppenheim, 1992). Strategies selected for carrying out research depend on the nature of the research question, personal experiences of the researcher and intended audience for the study (Robson, 1993; Creswell, 2009). An understanding of the research strategies available is required to make an appropriate choice from the three traditional strategies available - experimental, survey and case study research designs (Robson 1993). It is also possible to employ two or more strategies in a hybrid plan by combining aspects of each strategy (Robson 1993).

3.4 PILOT SURVEY

The purpose for piloting the survey included trying out the instrument of data collection; gaining access to respondents; gauging the suitability of respondents; evaluating competency of questionnaire while measuring survey time and clarity of questions (Oppenheim, 1992; Potts, 2001). The pilot survey was conducted over a period of ten months and included a few interviews in both countries. In total, there were fifteen responses out of twenty questionnaires sent and six interviews with two performed in Nigeria.

The twenty questions in the pilot survey were made up of fourteen dichotomous questions intended to verify the suitability of the criteria and factors; one Likert scale question to investigate the applicability of sustainability development in waste management and five ranking and rating questions to elicit the weightings for the aspects and factors. A description of the ranking and rating procedure is outlined in the second section of the questionnaire as presented in Appendix 1 of this report. A comments/suggestion section is placed at the last part of the survey while a request for respondent details is found in the first section.

Surveys have been suggested as the most effective tool for generating usable knowledge by social scientists and it is an appropriate research design for this study as it provided a quantitative description of the opinions of a population by studying a sample of that population (Lindblom and Cohen, 1979; Creswell, 2009). Surveys are representative of the real world situation as long as data is valid and reliable (Oppenheim, 1992). They work very effectively with providing wide range of information about a large and varied group(s) of people characteristics such as values and beliefs, and relationship between these characteristics (Robson, 1993).

Data elicited from standardized questions are relatively easier and cheaper to collect and reduce several types of errors (Robson, 1993). What has been taken into account is the fact that respondents may not necessarily report their characteristics accurately to show themselves in a good light. Furthermore, data may be affected by respondent characteristics such memory, motivation, knowledge and experience. Other factors considered will be highlighted in the questionnaire survey of Section 3.2.6 (Robson, 1993).

3.4.1 Participants of the Pilot Survey

The pilot survey participants in the UK were obtained through researchers' supervisors and authors of journal articles and conference proceedings. In Nigeria, they were found by identifying

offices of the waste management sector both public and private. Contact with participants in UK was established via e-mail while those in Nigeria had to be approached in person. The questionnaires were sent out and returned by post in the UK but were hand delivered and collected in Nigeria.

3.4.2 Postal questionnaire survey – Pilot

Postal questionnaires are commonly used research techniques for generating waste management data (Williams and Kelly, 2002; bench *et al*., 2005; Perry and Williams, 2007; Feo and Gisi, 2010). It is comparatively inexpensive, often quicker to administer and less prone to bias in comparison to collecting data via interviews (Dillman, 2005). As one of the oldest type of survey methods, it remains among the most prevalent means of collecting large quantities of information from geographically dispersed participants (Dillman, 2005; Bhattarai and Fosgate, 2010**)**. The major drawback is the failure of respondents to return questionnaire, which may jeopardize the study validity. Compared to the web survey, lower expertise is required for the design and construction of mail surveys and has the lowest level of wrong addresses and ensures that a single individual is sampled only once in the survey (Bachmann *et al.*, 2000).

The web survey was considered for gathering data but was discarded due to the lack of e-mail access for some respondents especially in the informal private sector group in Nigeria. This is in addition to lower response rates of the web survey compared to the mail survey despite time conservation from rapid return of questionnaires and data processing because data is captured in an electronic format (Akl *et al*., 2005; Shih and Fan, 2009)

Response rates of participants can be enhanced by many available techniques as cited in literature. These include questionnaire length, colour (Kalantar and Talley, 1999; Edwards *et al*., 2002; Beebe *et al*., 2007), questions of sensitive nature (Edwards *et al*., 2002) and follow-up (Hoffman *et al*., 1998; Edwards *et al*., 2002). Some of the techniques adopted in the pilot survey include preliminary notification and follow-up via e-mail in the UK and face to face approach in the case of Nigerian participants (Ashby *et al*., 2010). Pre-notification consisted of introducting the researcher and subject area of research to participant; a request for the details of the respondent and consent for questionnaire administration. Light green was the chosen colour for the questionnaires to enhance responses based on recommendation from previous work on questionnaire appearance (Connon, 2008). The length of questionnaire was minimised as much as

possible (to four pages) without compromising data collection requirements of the investigation to further boost response rates (Edwards *et al*., 2002).

The fact that practitioners are identified based on their experience and knowledge of the research area impacts favourably on the response rate. This is because previous studies suggest that questionnaires designed to be of more interest to participants were more likely to be returned (Oppenheim 1992; Edwards *et al*., 2002). Self addressed return envelops were included within the questionnaires sent to the participants to motivate response and return of questionnaires (Yammarino *et al*., 1991; Edward *et al*., 2002). As an additional motivation, sensitive questions were avoided to increase the likelihood of questionnaire return (Edward *et al*., 2002). This was relatively easy as the data sought is not of a sensitive nature.

The result of the pilot study indicated a move from the postal questionnaire survey to a structured questionnaire with the presence of the researcher. Some of the reasons for this change included the scope of study area being narrowed to Nigeria as a developing nation; request of participants for further explanation on the scale of measurement and topic content as well as the need for personal delivery and retrieval of questionnaires to participants specific to Nigeria. These factors are further explained in the structured questionnaire segment of this chapter (Section 3.3.9.1). A pilot study was performed that resulted in the selection of a structured face to face questionnaire rather than a postal questionnaire and the choice of AHP as a data collection technique.

3.5 The structured questionnaire survey

The structured questionnaire survey was designed to confirm the concept of sustainable development and its components suitable for generating a sustainability assessment model for solid waste management. Further discussion on the structured questionnaire survey is presented in Section 3.3.9. The aim was to be achieved by getting practitioners to assign relative weights based on priority to components of sustainable solid waste management on two levels. The breakdown of the concept is presented in a hierarchical form with three levels according to the method of Analytic Hierarchy Process (AHP) as depicted in Figure 3.1 of Section 3.3.7.1.

The data collection instrument altered from a ranking and rating method (see questionnaire in appendix 1) that required the participants to write out their options to a pairwise comparison scale of AHP with preferences of participants marked by researcher. This is in addition to the change from postal to structured questionnaire survey as stated in Section 3.2.2.2. The written

comments in the suggestion section of the questionnaire and discussion of the interviews showed that most individuals do not think in percentages as required by the rating and ranking procedure in the questionnaire. In the process of exploring a suitable method for data collection, an interview with research fellow, who had used AHP, was conducted to further evaluate suitability of AHP amongst the various multi-criteria techniques identified from literature (Wattage, 2009).

3.5.1 Sampling techniques and population

The population for the survey was made up of 87 practitioners in the waste management industry categorized according to work sectors and regions. Further explanation on the participant categorisation is presented in Sections 3.3.8 and 3.4. Two sampling techniques were adopted to ensure participation of practitioners. The multi-stage sampling technique involved identifying the work groups at the first stage and then locations were specified (Oppenheim, 1998; Robson, 2002). This sampling procedure is cost effective and saves time (Robson, 2002). Practitioners initially identified were contacted and used as links to reach other members of the population after they had responded to their questionnaires, which is a snowball sampling technique (Robson, 2002). The snowball sampling approach was effective in reducing the difficulty of identifying solid waste management practitioners due to poor use of the internet within the limited time prescribed for the survey (Robson, 2002).

The AHP was adopted to establish the preferences of the practitioners regarding the waste management components broken down into a three-step hierarchy as shown in Figure 3.1 of page 51.

3.5.2 Analytic Hierarchy Process (AHP)

AHP is a multi-criteria technique adopted as a data collection and analysis instrument, which provides an appropriate way of dealing with complex system(s) that have various components; diverse stakeholders and a wide range of criteria such as the sustainable waste management (Ramanathan, 2001; Zopounidis and Doumpos, 2002; Salhofer et al., 2007; Mwai et al., 2008; Vego et al., 2008).

It is a theory of measurement originally devised by Saaty (1980) through pairwise comparison that relies on the judgements of practitioners or stakeholders to derive priority scales for factors of an issue or system (Saaty, 2008). It is a quantifying tool (Soma, 2003) 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; 2008). The priority scales measure elements in relative terms. The comparisons are made using a scale of absolute judgements that represent how much one element dominates another with respect to a given attribute. The judgements may be inconsistent, and how to measure inconsistency and improve the judgements to obtain better consistency is a concern of the AHP (Bello-Dambatta *et al*., 2009).

3.5.3 AHP – The procedure

The AHP involves 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 pairwise 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

3.5.3.1 Hierarchical structure

A hierarchy is defined as a stratified system for organising 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. Hierarchical structures are validated by ensuring the structure is logical and complete (Saaty and Shih, 2009). In most cases, the elements are arranged from the more general and less controllable to the more specific and controllable (Saaty and Shih, 2009). This achieved by the breakdown of sustainability assessment of solid waste management into aspects and factors.

The hierarchical structure is constructed by

- Identifying the overall goal of the issue at the top of the hierarchy – Sustainability of waste management
- Identifying elements that made up the system and organising them in levels based on their connections and interrelations. Elements that have the same properties are grouped together and are related according to their influence on the next level

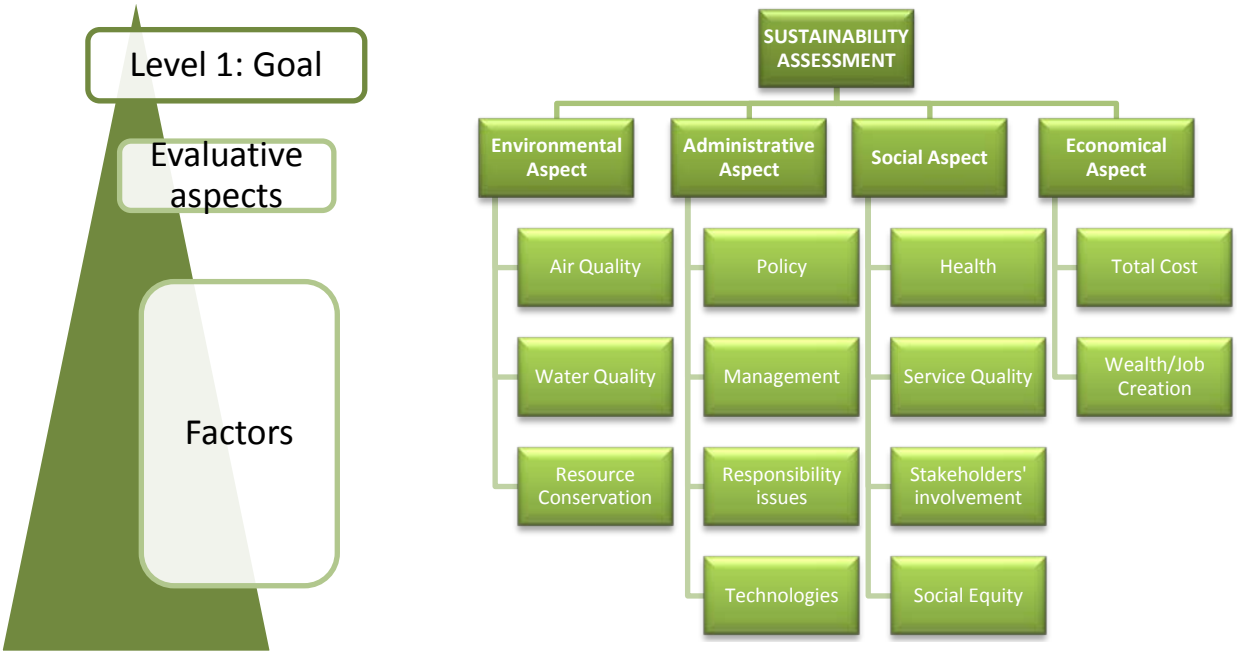


Figure 3.1 Hierarchical structure of waste management Sustainability Assessment

3.5.3.2 Pairwise comparisons

The AHP uses pairwise 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. An example of a pairwise comparison of two aspects (environmental versus administrative aspects) is shown in figure 4.2 with an accompanying scale interpretation.

As long as a considerable disparity does not exist between the activities and/or objects being compared, literature suggests that the bounded scale of one to nine is apt for the following reasons (Saaty, 1990):

- The ability of the human mind to make qualitative distinctions is represented by five attribute: equal, weak, strong, very strong and absolute. Because greater precision is normally required, compromises between adjacent attributes are made that lead to a total consecutive nine values
- Stimuli are divided into three regions of rejection, acceptance and indifference. Each of these regions is further subdivided into low, medium and high for precision. This in total indicates nine shades of meaningful distinctions

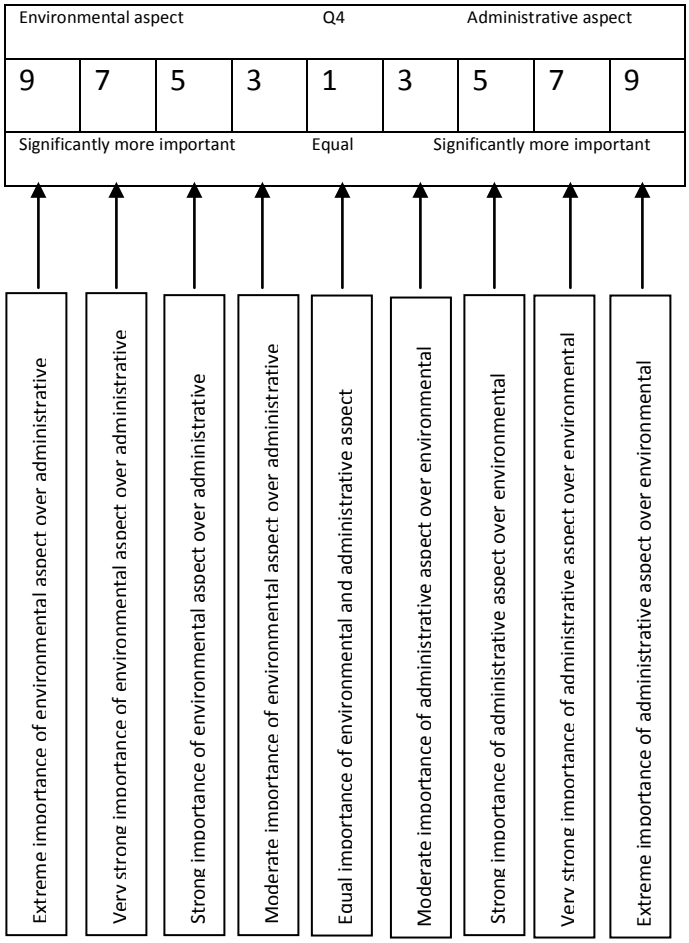


Figure 3.2 Example of pairwise comparison question from implemented survey with interpretation (Saaty, 1990; Wattage and Mardle, 2005; Pascoe *et al*., 2009; Expert Choice, 2004)

3.5.3.3 Relative Weights – Eigen value method

The relative weights and consistency ratios of judgements are obtained using relatively available easy to use software (EXPERT CHOICE). The priorities of elements are estimated by finding the principal eigenvector of a specific matrix (Saaty, 1980; Saaty, 2000; Ramanathan, 2001). The inconsistency of the judgemental matrix is determined by a consistency measure with a consistency ratio of 10% and less considered acceptable (Saaty, 1990).

3.5.3.4 Aggregating Relative weights

Final priorities of alternatives are aggregated once the priorities of elements are obtained (Saaty 1980; Ramanathan, 2001). The derived priory scales are synthesized by multiplying the weights of the lower level elements (factors) by the weights of their corresponding higher level elements (aspects) (Saaty, 2008). This is carried out by expert choice.

3.5.3.5 Expert choice software

The elements compared at a peer level using the pairwise 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).

Criteria for Environmental aspects

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

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

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

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

The matrix determined from the judgement is:

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

Reciprocals are automatically assigned in each pair-wise comparison and normalised to give (Al-Harbr, 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.

3.5.4 General application

AHP has been applied successfully 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 are 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 3.1 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 modelling 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 (Ramanthan, 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 organising 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).

In addition to fulfilling the criteria generally used in selecting a multi-criteria analysis technique of ease of use, transparency, internal consistency and logical soundness and software availability outlined above (Vaidya and Kumar, 2006; Dodgson *et al*., 2009), the decision process using AHP was found to be systematic and conserved time (Tam and Tummala, 2001).

Another important feature of the AHP as a quantifying tool is its ability to check and measure inconsistencies that generates awareness of users to the seriousness of inconsistent judgements as well as provides a means of minimizing the inconsistency (Saaty, 1980; Leung, 1998; Soma 2003; Saaty, 2008; Bello-Dambatta *et al*., 2009). In determining the weights of air quality, water quality and resource conservation for instance, if air quality and water quality are assigned equal weights, the inconsistency of the process will be high if resource conservation is not assigned the same or a very similar weight in the comparison between water quality versus resource conservation and air quality versus resource conservation. The accepted upper limit for the consistency ratio is 0.1, after which the evaluation procedure has to be repeated to improve consistency.

The nine-point comparison scale used to generate quantitative measurement is somewhat technical and requires a description (Soma, 2003). This nine-point scale is sometimes viewed as a limitation because some decision problems need larger scale (Wang and Yang, 2007). 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). Furthermore, 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. The original method used by the AHP (Saaty, 1977) to aggregate preferences allowed the rank order of the alternatives to change when alternatives are added or deleted (Millet and Saaty, 2000). The validity of the AHP became questionable because the rank reversals violated a principle of utility theory (Dyer, 1990; Harker and Vargas, 1990; Saaty, 1990). The rank reversal in AHP is caused by Eigen vector normalisation (Schenkerman, 1994) and can be avoided by employing the geometric mean and the weighted geometric mean rule that preserves

the underlying mathematical structures (Barzilai and Golany, 1994). However, proving this mathematically is beyond the scope of this study.

Table 3.1 Some studies employing AHP

Study	Country	Subject	Breakdown of Participants					Actors
			Govt	Academics	Private	Environmental groups	Other	
Leung *et al.*, 1998				12			22	34
Lai et al., 2002	Hong Kong	Multi-media					engrs	622
Winebrake and Creswick, 2003	Virginia, USA	Hydrogen fuelling systems						
Soma, 2003	Trinidad & Tobago	Fisheries Management	√		√			-
Wattage et al., 2005	English channel, UK	Fisheries management						24
Bottero and Peila, 2005	Turin, Italy	Sewer construction			√		public	400
Bertolilni et al., 2006	Italy	Public works						
Brent et al., 2007	S/Africa; Lesotho	SD & Waste Management	7	nil	7			11
Shin et al., 2007	Korea	Nuclear projects	√	√	√			48
Contreras et al., 2008	Boston, USA	Waste management	√	√		√		-
Sambasivan and Fei, 2008	Malaysia	EMS						22
Wattage and Mardle, 2008	Srilanka	Fisheries Management						200
Garfi et al., 2009	Algeria	Waste management	2		14	4		20
Garfi et al., 2009	Algeria		2		14	4		20
Chun-hsu Lin et al., 2010	Taiwan	E-Waste policy	4	6	4	4		18
Arnette et al., 2010	Virginia, US	Watershed management	19		5	9		33

In addition, The AHP method is a complete aggregation method of the additive type (Kamenetzky, 1982) 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.

3.5.4.1 AHP application in solid waste management

AHP was employed in this research via a questionnaire survey to determine the preference of practitioners on the issue 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, 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).

3.5.5 Participants

'Expert role has always played a significant, if often unrecognized, role in analysis' (Otway and von Winterfeldt 1992). Recent research has attempted to make it formal, explicit, and documented so it can be identified and reviewed by others (Otway and von Winterfeldt 1992). Taking time and resources into account, five locations, discussed in section 3.4, were deemed appropriate to represent the geographic locations in Nigeria that is a basic requirement for expert selection (Noble, 2004). Diversity of opinion and approach among practitioners, including independence in the knowledge that they contribute, as a fundamental criterion is further achieved by the four groups of expert identified and specified by previous studies shown in Table 4.1 (Otway and von Winterfeldt 1992). This in turn will ensure a dynamic and holistic tool for assessing waste management from the view point of all users is developed (Otway and von Winterfeldt 1992).

Four groups of practitioners for the questionnaire administration and AHP application are:

- Federal Government
- State/local government sector

- Private sector – Formal and informal
- Academic sector

The sectors of practitioners outlined represent individuals whose professional knowledge and value judgements are required to achieve realistic weightings of factors and aspects governing any waste management scheme. The four groups have been adopted in a combination of one two, three or all four in the studies outlined in Table 3.1. Value judgements are expressions of preferences among alternatives based on priorities or trade-offs (Otway and von Winterfeldt 1992). The informal sector managers, usually excluded, were incorporated due to their practical experience in the collection of solid waste (Afon, 2007). The informal sector managers are traditionally excluded in surveys due to the attitude of the waste authorities that tend to ignore their existence and the difficulty in making contact for interviews and discussions (Nwaka, 2005).

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 judgements are employed demonstrated in table 4.1. According to Turoff (1975), a participant number of ten is sufficient to make the required judgement(s) (Noble, 2004) particularly for AHP as supported by Sambasivan & Fei (2008). In most available studies (Table 4.1), the participants identified in AHP application are the government officials with all tiers represented, academic researchers, and private sector organizations and other individuals - manufacturer's, recyclers both in the formal and informal sector and environmental groups.

3.6 QUESTIONNAIRE SURVEY

The questionnaire survey was designed to determine the weightings of the factors and aspects that make up a sustainable waste management assessment scheme. This is in addition to verifying the concept of SD employed for evaluation of waste management schemes and its consequent breakdown into aspects and factors that influence these aspects.

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 is given prior to the questions. The pair wise comparison method of selecting preferences and the measure of their intensity is also described to enable the practitioners to make their choices. Respondents are given an exact copy of the questionnaire during the questionnaire administration.

3.6.1 Rationale for structured questionnaire survey

Questionnaire and interview surveys are commonly used to gather information on waste management practices and stakeholder preferences in both developed and developing nations (Petts, 2001; Mbuligwe, 2002; Barr, 2004; Mbuligwe and Kaseva, 2005; Fonta, 2008; Coker *et al*., 2009; Feo and Gisi, 2010; Cox *et al*., 2010).

A face to face structured questionnaire was deemed appropriate for obtaining expert value judgements on waste management in this case. The modification from a postal questionnaire was a result of the responses obtained from the pilot study.

The two most significant causes of adopting the structured questionnaire survey rather than the postal survey is first, the insistence of a large number of the practitioners in Nigeria requesting for the presence of the researcher for clarification. This is because most of the practitioners had not used a ranking system in a questionnaire administration. Diagrams and explanations simplified the idea that needed to be communicated to the respondents. The structured questionnaire survey also proved invaluable in the case of the informal private sector respondents who were mostly illiterate and had language difficulties in some locations.

Secondly, despite the pilot study being a postal questionnaire, the questionnaires had to be hand delivered to the vast majority of the respondents in Nigeria. In addition, the completed questionnaires had to be obtained in person. Due to these circumstances, the vital advantages of

the postal questionnaire were reversed. The low cost of data collection and time conservation were greatly diminished due to delivery and collection of the questionnaire as well as the ability to reach widely dispersed respondents (Oppenheim, 1992). This situation is due to an unreliable postal service and the inability to establish contact with respondents via phone or e-mail.

The presence of the researcher in conjunction with other techniques checked incomplete responses and incomplete questionnaires and also enhanced responses of participants. Furthermore, it ensured that the practitioners identified due to their in-depth and wide knowledge of the survey topic actually responded to the elements in the questionnaire themselves. However, the presence of the researcher may negatively affect the quality of the information obtained as it discourages consultation of documentary evidence due to time pressure (Oppenheim, 1992).

Despite the benefits of the structured questionnaire survey, it has some disadvantages that in no way invalidate the data collected. Biases are difficult to rule out. In the same vein in which non-verbal cues of respondents may help in understanding verbal response, non-verbal impression on the respondent may result in a pre-empted, conditioned response(s) (Robson, 1993). In any case, the interviewer bias is not totally ruled out in the postal questionnaire survey as the respondents still interacts with the questionnaire and may project some kind of person or organisation behind the questions (Oppenheim, 1992).

3.6.2 Participant cooperation

Participant cooperation for questionnaire surveys can be ensured by many factors as indicated in the literature base.

Preliminary notification to get the attention of participants has been established as one of the key factors that enhances cooperation of respondents in a survey by at about a third (Fox, 1988; Yammarino, 1991; Edwards *et al*., 2002). Pre-notification was partially achieved in the study for all locations in the survey. As most of the participants had to be physically approached, appointments were made on first and second day of arrival for four to five days of interviews. Phone calls were made to establish contacts for more respondents obtained from the initial participants to administer the questionnaires. In many cases when participants are approached physically, questionnaires were administered once contact was established. Details of respondents were obtained during pre-notification process for personalisation, which enhances response rates (McCoy and Hargie, 2007).

An explanation of how an expert was chosen was employed using an introductory letter to boost response of participants via e-mail for those that had access (Oppenheim, 1992). The first set of participants provided contact details for the rest of the sampled population (snowball sampling technique). All other practitioners were made aware of how their details were obtained while many were contacted by the initial participants to introduce the researcher beforehand. Another motivating factor for response was providing an explanation to potential respondents of the select few chosen for the survey due to their expertise and knowledge (Dillman, 2009).

Research findings suggest that shorter questionnaires elicit more responses (Dillman *et al*., 1993; Edwards *et al*., 2004; Jepson *et al*., 2005) though a few researchers were unable to establish a relationship between length and response (Herberlein, 1978). A five page thirty-three question survey was developed with as few pages as possible to encourage response without compromising data collection requirements of the investigation.

Other factors that persuade response to questionnaires are anonymity and confidentiality (Oppenheim, 1998). All respondents in this study were identified by a code at the data processing stage even though the research topic is not particularly of a sensitive nature. As names are not mentioned in the report, anonymity and confidentiality were further ensured. Also, no information was published about identifiable individual(s).

Questionnaires designed to be of more interest to participants or believed to be in their line of influence are more likely to be responded to (Oppenheim, 1998; Edwards *et al*., 2002). All respondents are directly involved in waste management as they are practitioners in the field. It therefore suggests that the research topic is of importance to them and they are knowledgeable and interested in the topic (Yammarino *et al*., 1991). In addition, many of the practitioners are in the government sector and may directly influence decisions in the waste management industry.

The questions were kept simple and unobtrusive with few personal details required mainly for feedback purposes. Questionnaires containing questions of a sensitive nature were less likely to be returned (Dillman *et al*., 1993; Edwards *et al*., 2002). It was possible to maintain the unobtrusive nature of the survey as it was not after personal information. Furthermore, questionnaires from institutions such as universities and the military motivate response compared to marketing and other survey sources (Fox *et al*., 1988; Edward *et al*., 2002).

Although these factors combine in a synergy to improve the response rate of the survey, the most significant attributes that encouraged higher response rate were the presence of the researcher

and personal delivery and collection of the questionnaire. It has been identified by studies that the appearance of questionnaires affects the response rate (LaGarce, 1995).

3.6.3 Questionnaire construction

The questionnaire survey consists primarily of closed ended questions with comments/ suggestion section at the tail end being the exception. The closed ended questions were mostly scale questions, which were limited to a set of responses to be ticked, circled or underlined (Oppenheim, 1991), with a few dichotomous and fixed alternative questions. The ordinal scale closed-ended questions are used in this survey because they can measure intensity of opinions on a comparison scale (Dillman, 2009).

All relevant aspects and factors of waste management necessary for its assessment are outlined in order to obtain weightings using comparison-scale questions in the questionnaire. To enhance responses and reduce ambiguity, the spacing maintained between answer categories is consistent with the measurement intent while balanced scales provided effective comparison (Dillman, 2009). In addition, the length of scale is limited to five categories on each side of the comparison scale in line with the methodology of AHP adopted in the questionnaire and as suggested in previous research (Saaty, 1990; Dillman, 2009). The response options were aligned horizontally in a row with equal distance between categories to demonstrate an inherent order. This is with a view to get respondents to understand how the options are presented quickly and to process them in the intended order.

The use of fully labelled scale was avoided to reduce the length of the questionnaire and repetition though previous research has shown that it elicits positive ratings (Dillman, 2009). This comparison scale is further discussed in the AHP section.

The advantages of the closed questions generally outweigh the open questions provided appropriate responses can be generated and categorized (Robson, 1993). As quantification is straight-forward, the closed questions are easier to code, process and analyse. They are also easier and quicker to answer because no writing is required (Openheim, 1992). Because time is conserved using these types of questions, cost is normally reduced. In terms of appearance, the closed-ended question questionnaires are shorter and hence, encourage responses.

Although respondent ideas, which may serve as basis for new hypotheses, tend to be eliminated with the use of close-ended questions (Robson, 1993), some of the richness of open questions is

lost inevitably during classification (data processing and analysis) in any case (Oppenheim, 1992). The comments/suggestion section at the end of the questionnaire provides an opportunity for the respondents to bring up issues not covered in the questions. This is in addition to comments encouraged by researcher during the questionnaire administration.

3.6.4 Questionnaire sequence

The questionnaire consists of four sections with details as follows:

- An overview of the aim of investigation.
- The dichotomous questions in the first section used to validate sustainable development and suitability of its breakdown.
- The middle and majority questions were the scale questions that assigned the weightings to the aspects and factors of waste management with a total of twenty-five questions. The fixed alternative questions at the end elicited respondent details
- Finally, the comments/suggestion section.

The participants were eased into the process of responding when asked the relatively simpler questions at the beginning of the survey (Dillman, 2009). Personal questions that tend to be sensitive are placed at the end of the questionnaire after a few questions that were placed for cooling off as well as for their primary aim of generating data.

Questions are grouped into sections based on their theme such as aspects of '*waste management sustainability*' and *'factors of environmental aspect'* to increase clarity (Dillman, 2009). Research has shown that people normally begin to read from the upper left corner of the left hand page and proceed down the page (Dillman, 2009) and therefore, the questionnaire was organized that way. It was also arranged in a logical manner based on a top down approach so that effects of earlier questions on later questions were decreased (Dillman, 2009; Oppenheim 1992). The arrangement also enhanced an understanding of the previous questions that was necessary to answer the subsequent questions (Dillman, 2009).

3.7 STUDY LOCATIONS

The survey was carried out in five locations to capture Nigeria's multiple ethnic groups and diverse cultures; Abuja, Lagos, Kaduna, Maiduguri suggests 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 that takes up approximately 35% of the country is represented by Maiduguri in the north-east while the montane and high forest zones, very close to the fresh water swamp and guinea savannah are not covered due to time and resource constraint (Adejuwon, 2006). In addition, the areas covered by the other five zones are small compared to sudan and guinea savannah. Abuja situated within the guinea savannah climatic zone is adopted as the federal capital territory, which captures many ethnic groups that exist across the country.

Table 3.2 illustrates the respondent ratios across the five regions and four sectors adopted in the study. The following Sections 3.4.1 to 3.4.5 document the survey across the five regions.

Table 3.2 Survey locations and sectors

Locations / **Sectors**		**Abuja**	**Kaduna**	**Lagos**	**Maiduguri**	**Port-Harcourt**	**Total**	
Central govt		**7**	**5**	**3**	**2**	**2**	**19**	
State govt		**7**	**6**	**4**	**10**	**5**	**32**	
Private	**Informal**	**1**	**4**	**1**	**-**	**1**	**7**	**16**
	Formal	**2**	**1**	**2**	**1**	**3**	**9**	
Academic		**2**	**6**	**1**	**6**	**5**	**20**	
Total		**19**	**22**	**11**	**19**	**16**	**87**	

3.7.1 Abuja

In the Federal Capital Territory Abuja, a total of 19 respondents across all sectors responded to the questionnaires. Unsurprisingly, it has the highest number of central tier government ratio among all the cities as it is the seat of the federal government. The state government sector is quite active in the region and is responsible for collection, transport, treatment and disposal of waste in FCT. Contacting respondents of federal and state government sectors in Abuja was not very difficult as

the respondents were centred each in one office building. These offices are well known and easily accessible in the central district of the city. The low numbers of academic and private sector respondents is accounted for by a combination of time constraint and inaccessibility.

3.7.2 Kaduna

Twenty-two respondents were questioned almost evenly across all sectors in this northern town of Nigeria as shown in Table 3.2. The state government sector was the most accessible in this region with the respondents located mainly in two well known office buildings within Kaduna town. The central government respondents were also situated in two buildings within the city but their offices were more difficult to locate and appointments not as easily made. The academic sector respondents were found in two higher institutions: the first within the city and the second, about forty-five minutes away from town. All private sector participants were found in different locations.

3.7.3 Lagos

The first location to be visited was Lagos, the old capital city of Nigeria with the lowest respondent rate of eleven across all sectors. Many of the federal government offices are still functioning and as such, central government survey was completed in a day. The participants were situated in the same office building within the city. The state government are very active in providing waste management services in the state and were easily located in the same office building. Academic sector participation was poor as the university was on strike during the field work such that staff and students were generally unavailable. Locating the private sector respondents was very difficult, which accounts for their low number.

Fig 3.3 Map of Nigeria showing survey locations (World of Maps.net)

3.7.4 Maiduguri

Maiduguri accounted for nineteen out of eighty-seven participants in the survey. The highest number of participants was from the state government sector responsible for waste management and located in three well-known buildings in the city. Private sector participation was is generally low and is apparent in the low representation in the survey. Academic sector respondents were easily found in the University of Maiduguri in four departments - Civil engineering; geology; geography and mechanical engineering.

3.4.5 Port-Harcourt

The total number of participants in Port-Harcourt was sixteen with a fairly even distribution across sectors. This region has a well-established private sector in the environmental quality arena similar to Kaduna. The city boasts two higher institutions where the academic sector respondents were situated. The central government participants were located in a single building within the city.

3.8 DATA PROCESSING AND ANALYSIS

Data from individual questionnaires was analysed 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.

3.9 SUMMARY

Review of literature identified sustainable development as a suitable concept to use in building an assessment tool. The tool was based on identifying evaluative aspects based on the principles of sustainable development that include the three traditional environmental, social and economic aspects and the addition of administrative aspect that has gained prominence in the recent past (van de Klundert, 2000; McDougall and White, 2001; Chung and Lo, 2003; Joseph, 2006).

Structured questionnaire survey administered by researcher employed after an initial pilot survey using postal questionnaire survey generated an equation from weightings assigned by solid waste management practitioners in Nigeria. The adjustment was necessitated by request of participants for further explanation on the scale of measurement and topic content as well as the need for personal delivery and retrieval of questionnaires to participants specific to Nigeria. The function is designed to be used in illustrating the sustainability of specified solid waste management schemes. The eighty-seven practitioners surveyed represent the work sectors and diverse regions in Nigeria. Individual weightings were determined with the application of AHP while general function was established using statistical analysis.

The next chapter, Chapter four, will illustrate and discuss the results obtained from the questionnaire survey with reference to the literature reviewed in Section two.

4.0 RESULTS AND DISCUSSION OF QUESTIONNAIRE AND LITERATURE SURVEY

4.1 INTRODUCTION

This chapter presents the findings generated from the structured questionnaire and literature survey administered to solid waste management practitioners. From the review of literature, sustainable development and its breakdown into measurable units is determined as a concept to base the appraisal of solid waste management. The result of the structured questionnaire survey designed to quantify sustainability as a means of assessing solid waste management is shown. The findings also illustrate the support of the practitioners for the application of SD as a concept to build an assessment tool for solid waste management and its subsequent breakdown.

The data collected from practitioners was analysed to show the overall significance apportioned to each aspect and factor (measurable units) that was employed to derive a sustainability function to appraise waste management strategies. In addition, the weightings assigned by the five regions and four sectors are presented and significant statistical differences mainly across the regions illustrated.

4.2 SUSTAINABLE DEVELOPMENT CONCEPT

The concept of sustainable development and its principles with respect to solid waste management assessment are addressed in this section.

There was general support from practitioners for the application of SD as a concept to build an assessment tool for solid waste management and its subsequent breakdown into measurable units. Out of the eighty-seven practitioners surveyed, 100% regarded SD suitable for the proposed development while less than ten percent indicated a need for regrouping of some factors of the four aspects. This may be due to the versatility and holistic nature of the concept in considering this generation and the succeeding generations as well as its ability to examine all aspects of a system while taking into account the many functional elements of solid waste management (Chung and Lo, 2003; Desmond, 2006; Imran *et al*., 2008).

Although there is a strong agreement across the environmental and waste management field on the basic principles and elements of the concept as well as many of the criteria used in

characterising or measuring the system, the choice of grouped criteria vary across studies. This is reflected among the practitioners in Nigeria by the small percentage that indicated the need for regrouping. Generic aspects of sustainable waste management of social, economic and environment are maintained by many researchers (Salhofer *et al*., 2007; den Boer *et al*., 2007; Imran *et al*., 2008; Klang *et al*., 2008) while others have adopted additional aspects with the most prominent being the administrative aspect (Chung and Lo, 2003; Desmond 2006). Another study has established four principles and specified human and institutional aspects very similar to social and administrative aspects respectively in addition to economic and environmental aspects (Agamuthu *et al*., 2009). Policy and technical issues have been established as factors under administrative aspect in this study, while they have been identified as main aspects by Anschutz *et al*. at the same level with economic, social, environment and institutional aspects (2004).

A tendency not to incorporate the administrative dimension, especially policy, in environmental research has been suggested as a major contribution in 'underdevelopment of intellectual capital' in the field (Davoudi 2006). Policy research, that includes evidence based and user-relevant studies, is relatively new as it was considered the responsibility of the government to gather data to facilitate decision making (Davoudi, 2006; Agamuthu, 2010). Cooperation between academia and waste managers and application of research interfaces though not seamless and without problems are beneficial to both parties and vital to waste management progress (Davoudi, 2006; Agamuthu and Hansen, 2007). Benefits include research collaboration based on real world cases, enhanced career development and capacity building (Agamuthu and Hansen, 2007)

4.3 SUSTAINABILITY ASSESSMENT TOOL

The developed assessment tool was derived in conjunction with a function that can be used to establish an index of a given solid waste management strategy. AHP as outlined in Section 3.2.5.4 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 and outlined in section 3.2.5.2.

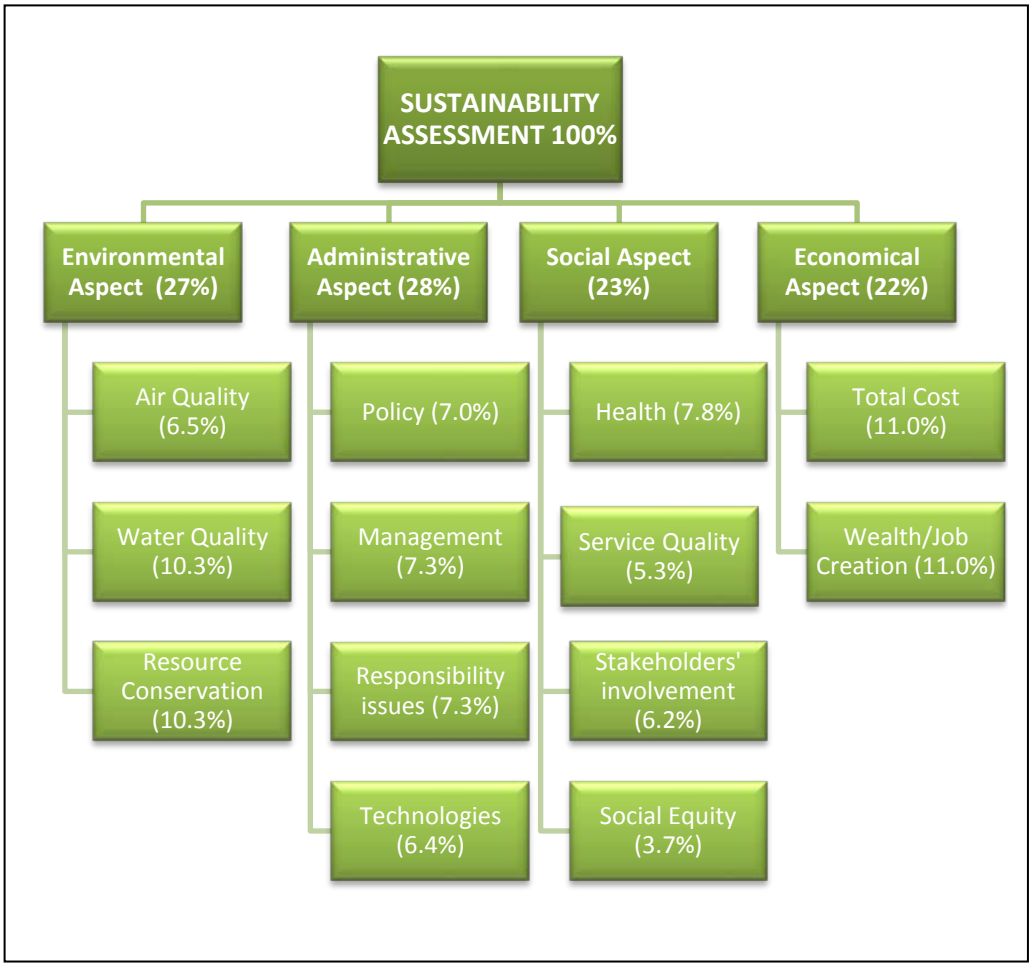


Figure 4.1 Hierarchical diagram of the aspects and factors of solid waste management sustainability assessment with weightings (Source - Original)

4.3.1 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.

Equation 1

$$\begin{aligned} SI = {} & 0.065\mathbf{I_{1i}} + 0.103\mathbf{I_{2i}} + 0.103\mathbf{I_{3i}} + 0.07\mathbf{J_{1i}} + 0.073\mathbf{J_{2i}} + 0.073\mathbf{J_{3i}} \\ & + 0.064\mathbf{J_{4i}} + 0.078\mathbf{K_{1i}} + 0.053\mathbf{K_{2i}} + 0.062\mathbf{K_{3i}} + 0.037\mathbf{K_{4i}} \\ & + 0.11\mathbf{L_{1i}} + 0.11\mathbf{L_{2i}} \end{aligned}$$

Table 4.1 presents the description of the parameters in Equation one.

Table 4.1 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	

4.4 SUSTAINABILITY ASSESSMENT ASPECTS

The four aspects of sustainability (environmental, administrative, social and economic) were found to have different weightings within a close range of 22-28%. Administrative aspect was the most significant aspect despite its absence as a generic principle of sustainable development in the past (McDougall and White, 2001; den Boer *et al*., 2007; Salhofer *et al*., 2007; Imran *et al*., 2008; Klang *et al*., 2008). The environmental aspect was found to be a close second while the economic aspect was established as the least important. Finally, the social aspect with a rating of 23% was found to be second to the last. Most studies in the area of sustainability of solid waste management imply or explicitly adopt the equality of the evaluative aspects (Bosshard, 2000; McDougall and White, 2001; Chung and Lo, 2003; den Boer *et al*., 2007; Imran *et al*., 2008). Distinct coefficients have been assigned to each aspect and factor that establishes their significance and indicates areas of emphasis during assessment. However, this does not signal an exclusion of any factor or aspect as the process is not about elimination but prioritization. This study has established that though close in importance, some aspects and factors have greater priority over others.

4.4.1 Administrative aspect

The administrative aspect is particularly relevant to Nigeria with inherent inadequate policies; implementation and enforcement issues; and ambiguity in responsibilities and relationships of waste managers, agencies and stakeholders (Ogu, 2000; Ayotamuno and Gobo, 2004). In addition

there are frequent incidences of unsuitable application of technologies coupled with inadequate infrastructure, skill and waste handling arrangement(s) (Adedibu 1988; Adedibu, 1989; Ogu, 2000).

4.4.2 Environmental aspect

Environmental issues focus on uncontrolled emissions; constant and direct contact with waste due to open dumps; and an imbalanced depletion of resources. Issues of over-exploitation of renewable and non-renewable resources are paramount under the environmental aspect with so many resources exploited beyond limits for sustainable development (Moxnes, 1998). Well-being is a function of a sufficiently clean and attractive environment (Opschoor and Reinjnders, 1991). Garrod and Willis (1998) studies has shown that although disamenity caused by a landfill site had no significant negative response from surrounding residents, the amenity value of open spaces is an issue especially with the open dumps prevalent in Nigeria.

4.4.3 Social aspect

Social issues include awareness, consensus and participation of stakeholders that is essential for effective management strategy with various techniques applied to disseminate information to different target groups in many countries (Petts, 2000). Effective management will ensure the basic priority of ensuring human health and well-being in the present and future generations. Due to low awareness levels of solid waste issues and strategies of stakeholders in Nigeria, it appears the existing awareness programmes (usually in the form of seminars, conferences and media) are inadequate (Imam *et al*., 2008; Nabegu, 2010). However, it has been suggested that lack of follow-up after the conferences, workshops and seminars is the major issue contributing to low awareness (Zavodska and Uhuo, 2010). Change in waste handling practices due to better awareness generally improves the state of the environment (Babalola et al., 2010).

Furthermore, environmental emissions from inadequately managed solid waste bring about health and safety problems (Caincross and Feachem, 1993 pg 16). This is in addition to the presence of disease vectors on open dumps prevalent in Nigerian urban centres that spread diseases and negative impact on the economy due to lost working days and treatment and mitigation costs (Joseph, 2006).

4.4.4 Economic aspect

Though its importance is rated the lowest, determining the least expensive waste management strategy that ensures adequate revenue for continuous operation and aftercare expenses is essential (den Boer *et al*., 2007). It becomes more so in situations where funding and affordability are among the main constraints and challenges of solid waste management such as in Nigeria (Imam *et al*., 2008). Full cost analysis is also critical to ascertain required revenue that will maintain consistent operation and to establish a fair and realistic fund recovery system for services (van de Klundert and Lardinois, 1995). Furthermore, there is a need to improve employment opportunities and reduce poverty for the informal sector people working with waste who ultimately reduce and divert waste going to final disposal (Diaz *et al*., 1996; Kaseva *et al*., 2002; Baud, 2002; Hayward and Gaskin, 2005). Generally, informal sector participation is a unique feature in developing countries management of solid waste and the sector is mainly responsible for resource recovery in Nigeria (Imam *et al*., 2008).

4.4.5 Aspects of sustainability assessment by sector

Although a general function is determined, the work sectors and regions have differences in the significance accorded to the various aspects and factors. Variations and similarities between the weightings of waste management assessment aspects and factors were determined by application of statistical test for differences. This was performed with Kruskal Wallis test using Minitab 15 where $p<0.05$ denotes the categories with significant statistical differences. The information is illustrated in Figure 4.2. In addition, the various sector weightings are compared to the overall weightings.

There is general agreement recorded between sectors with differences found in the environment and social evaluative aspects. These variations are caused by the private and state government sectors where the private sector weightings are the most distinct in both instances. The private sector has assigned considerably higher values to the social aspect and lower to the environmental while the state government sector accorded higher to the environmental and lower to social. The private sector is composed of the most varied set of respondents especially in terms of age and educational background. Where other sectors are composed of respondents with a minimum educational qualification of a higher education degree and a lower age limit of twenty-five years, the private sector includes the informal sector that are mostly young, predominantly male with little or no formal education (Afon, 2007). Lower educational qualification is recorded for the state

government sector in addition to lower experience and exposure compared to the academic and central government sectors.

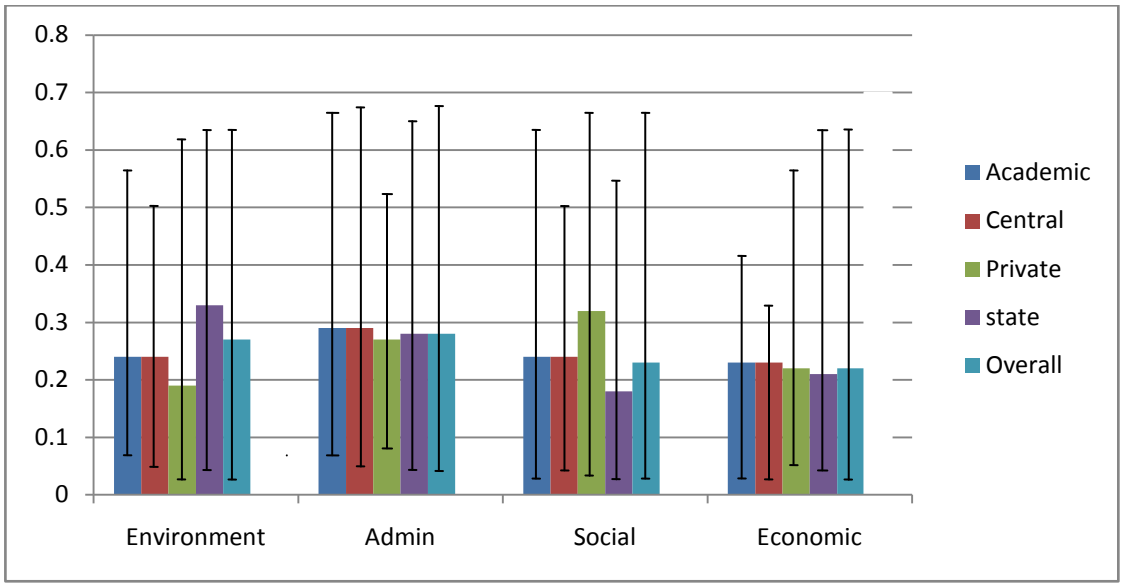


Figure 4.2 Aspects of sustainability assessment by sector

4.4.6 Aspects of sustainability assessment by region

The weightings accorded to the aspects by region of waste management sustainability assessment are demonstrated in Figure 4.3. Statistical differences do not exist within the aspects of sustainability with p values of 0.82, 0.36, 0.59 and 0.14 for environmental, administrative, social and economic aspects respectively. However, disparities are more pronounced than the weightings assigned by the sectors.

Variations are more distinct in the social and economic aspects across all regions and the most diverse weightings were generated by Maiduguri and Lagos. The variations of Lagos are the most distinct due to a considerably higher weighting established for the environmental aspect and lower for the administrative aspect that are in general accord by the other regions. Differences recorded between factors and aspects mainly across regions (statistically significant or otherwise) reflect issues of concern peculiar to the region while these issues are perceived in a similar manner across sectors regardless of their locations. For instance, due to high population density of Lagos and geographical situation (as it is surrounded by water), waste dumps create greater environmental pollution and contamination and hence the high rating of environmental aspect as it is an immediate concern compared to other locations. Labelled as one of the dirtiest cities in

Nigeria, Lagos is battling with inherent problems of air emissions and open dumps blocking drains and roads (Kofoworola, 2007).

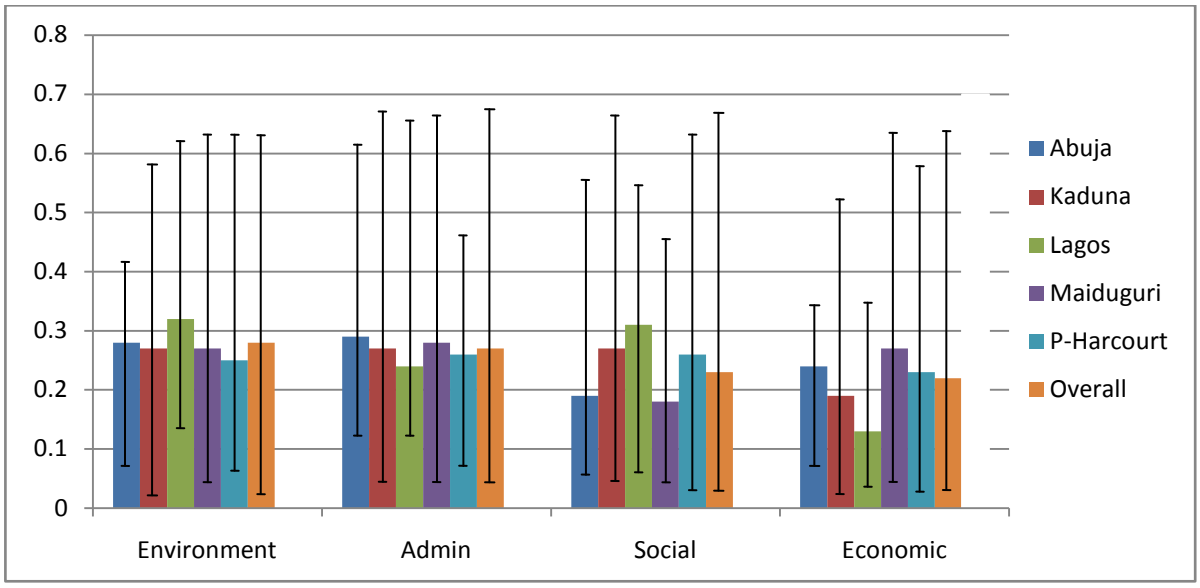


Figure 4.3 Aspects of sustainability assessment by region

4.5 FACTORS OF SUSTAINABILITY ASSESSMENT

The weightings assigned to factors of the sustainability assessment are presented in the Sections 4.4.1 and 4.4.2. These thirteen factors are the third level of the sustainability assessment of solid waste management hierarchy and a further division of the four evaluative aspects categorized into environmental, social, economic and administrative factors as depicted in Figure 4.1 of this chapter. The Figures 4.4 and 4.5 illustrate relationships of factors across regions and sectors and compared to overall weightings.

4.5.1 Environmental factors

The overall weightings assigned to environmental factors show water quality and resource conservation to be equal as the most important factors while air quality is the least important at 24%. A strategy that emphasizes waste minimization and recycling conserves resources used for managing waste and counteracting over-exploitation of renewable and non-renewable resources (Kaseva and Mbuligwe, 2003). Furthermore, greater waste minimization will reduce negative effects on water and air quality as a result of decrease in waste available for treating, burning and/or dumping. Water quality is regarded as equal in importance to resource conservation and greater than air quality due to its far reaching effects on the populace compared to air. There are a

high percentage of people without access to potable water in Nigeria and contamination of the scarce water is also a major issue. Air pollution from solid waste has been found to be negligible compared to other sources such as transport and industries (Akeredolu, 1988; Oluwakoropo, 2007). The major air pollution due to solid waste is smoke from open burning, which generally affects a small area over a short period of time. Contaminated water as a result of leachate on the other hand travels over a larger area and generally retains its harmful capacity for longer periods (Olaniyan *et al*., 2009; Abdullahi *et al*., 2010).

4.5.1.1 Environmental factors by sector

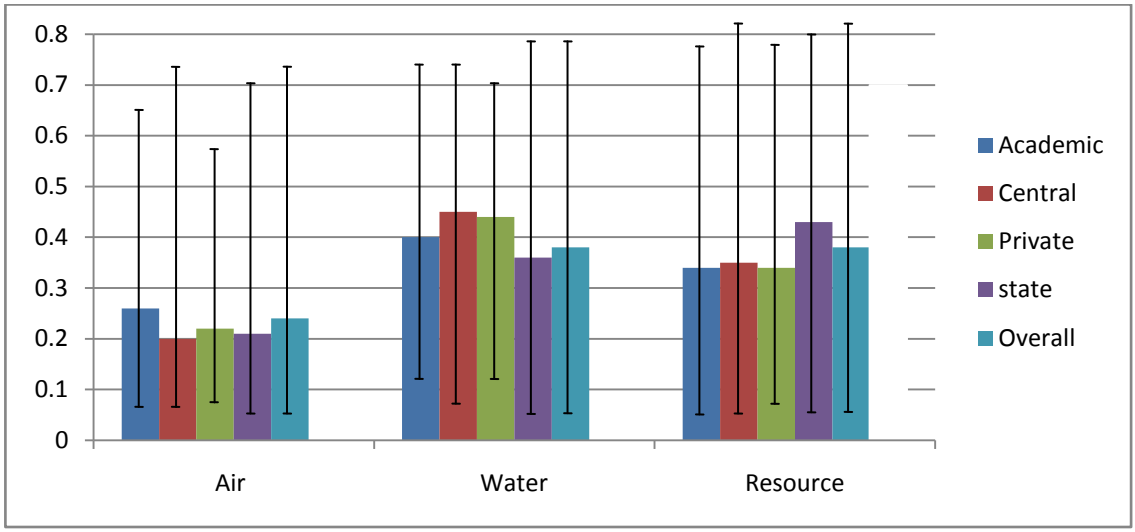


FIGURE 4.5.1.1 ENVIRONMENTAL FACTORS BY SECTORS

General consensus is established across the four sectors with differences of less than 10% across the environmental factors. This is illustrated in figure 4.5.1.1 and p values greater than 0.05, where air quality is 0.37, water quality is 0.67 and resource conservation is 0.23 across the sectors.

4.5.1.2 Environmental factors by region

Significant statistical difference is recorded between regions for all the environmental factors (with p = 0.001, 0.001 and 0 for air quality, water quality and resource conservation respectively). This is demonstrated by the wide variations in the weightings assigned to the three factors by the different regions. Although air quality has been established as the least significant factor, it was rated highest with a large value of 50% by Lagos and the second most significant by Port-Harcourt. This situation is similar to Maiduguri rating resource conservation as the most significant at 68% compared to its overall value of 38%, and equal in significance to water quality. The regions agreed the most on water quality, which has the least variation compared to the other factors, but it has a

broad range of 33% between the regions. The relationships between regions and a comparison with the overall weightings are illustrated in Figure 4.5.1.2.

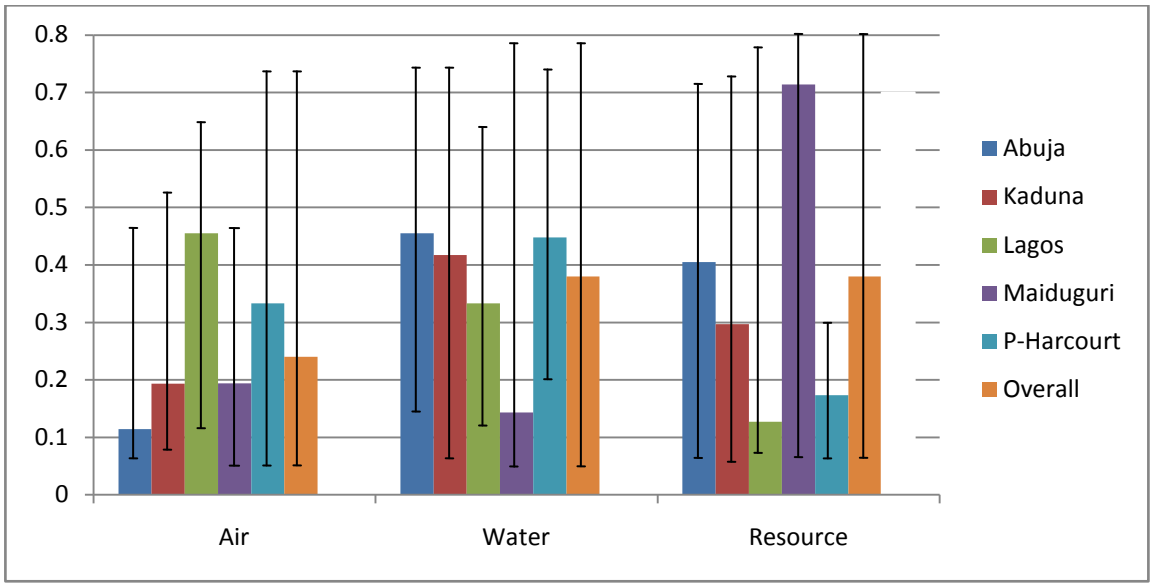


Figure 4.5.1.2 Environmental factors by region

As stated in section 4.3.1 the significances attached to aspects and factors reflect problem areas peculiar to that region or sector. The notable high priority given to air quality in Lagos compared to other locations is attributed to their air emission problems that has heightened the awareness of stakeholders even though the contribution of solid waste to air pollution is minimal (estimated at 2.1%) (kofoworola, 2007; Oluwoporoku, 2007). The high significance associated with resource conservation in Maiduguri may be due to their relatively high recyclable composition of the waste compared to the other regions while recycling rates are similar to those of other locations (Dauda and Osita, 2003; Ogwueleka, 2009). It was also gathered from the survey generally that once the resources are conserved, amount of generated waste reduces which in turn decreases the level of contamination and pollution.

4.5.3 Administrative factors

The overall factors of administrative sustainability assessment have similar significances of 23% to 26%. Management and responsibility issues are the most significant with equal weightings. The least important factor is technology that is lower than policy by 2%. The relationship between administrative factors across sectors is shown in Figure 4.5.2.1.

Governance is an integral part of solid waste management that specifies the manner in which waste is managed by the society (Imran *et al*, 2008). It involves the development of comprehensive policy framework and an adequate administrative capacity to implement the policies (Chung and Lo, 2003). Although most developing nations have established laws and set up departments and agencies to deal with their environmental problems, desired results have not been achieved in Nigeria (Bell 2002; Adelegan, 2004). The main problem is wholesome copying of modern waste management strategies while discounting a regions social harmony, local traditions and finances that can be partly attributed to quality of personnel (Abdullahi *et al*., 2008). This is in addition to lack of proper investigation into the success or failure of the strategies being copied. Despite advances of the developing nations and apparent successes, some strategies fail to meet specified targets (Umoh and Izugbara, 2004). Furthermore, progress for an enhanced environment in Nigeria generally still relies on a philosophy of pollution control rather than well planned strategies including solid waste management (Olukesusi, 1987; Egbu, 2000; Umoh and Izugbara, 2004). Other problems that indicate a need for more experienced and better trained personnel include function overlap of staff and agencies, frequent breakdown of machinery and irregular waste collection (Adedibu 1988; Imam *et al*., 2008; Adewole, 2009).

Policy is rated lower than management and responsibility issues because implementation and enforcement are more problematic in Nigeria. The existing policies are not completely implemented and enforcement is generally sporadic (Imam *et al*., 2008). In situations with policy appropriately defined, the outlined problems persist due to improper management structure and responsibility allocation. The general consensus of the Nigerian practitioners, obtained in the course of the survey, is that an improved policy framework and better equipped personnel will ensure proper technologies employed to manage waste and hence the choice of technologies as the least important administrative factor.

4.5.2.1 Administrative factors by sector

The pattern followed by all sectors is close to the overall function. The smallest variation between sectors is recorded in central government sector. The largest variation is established by the private sector in the management category, where statistical difference exists ($p = 0.028$). The statistical difference found is due to the management factor established as the least significant factor by the central government sector but as the most significant by the private sector. The state government sector has also selected it as the most important factor but equal to technology. In addition, it was

maintained as the most significant factor by the academic sector but equal to technology and responsibility issues.

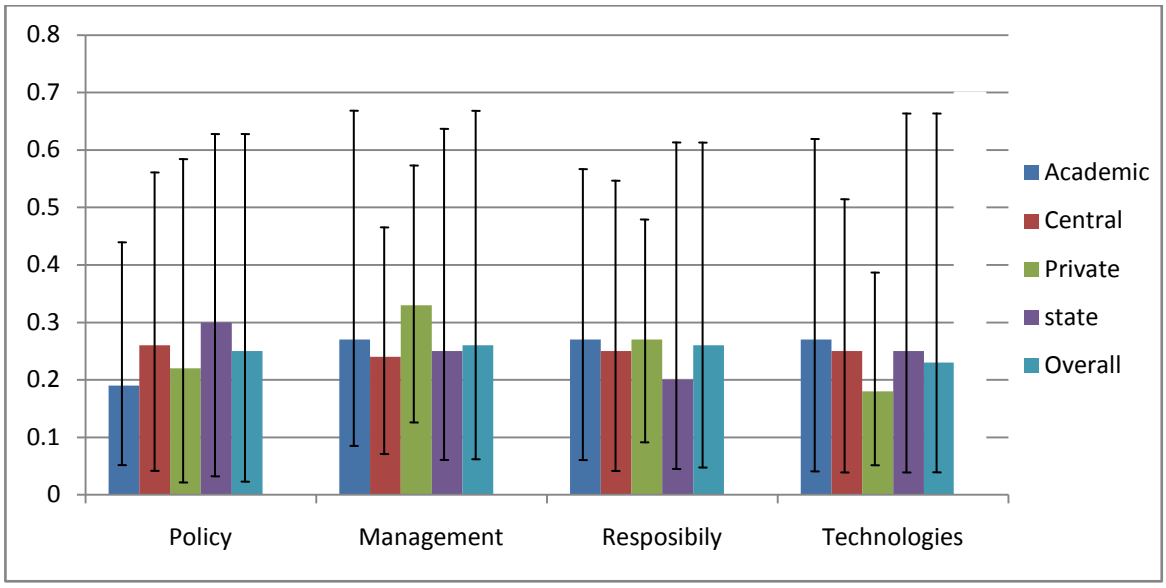


Figure 4.5.2.1 Administrative factors by sector

The private and state/local government sector have established management and responsibility issues as key to the management strategy due to direct responsibility for managing waste (Afon, 2007; Ogbonna *et al*, 2007; Afon and Okewole, 2007). They are therefore more likely to understand better the challenges inherent in the management of solid wastes. The central government sector is essentially in charge of policy generation with little involvement in the management processes (Walling *et al*., 2004; Imam *et al*., 2008). The academics are in agreement with the private and state government sectors have chosen management as the most important mainly due to inadequate and lack of consistent research in the waste management field and therefore scarce data (Wilson *et al*., 2009).

4.5.2.2 Administrative factors by region

In the region category, statistical significant difference is recorded for management and responsibility issues, where p = 0.012 and 0.014 respectively. The disparity in the management factor is due to the notably high weighting assigned by Port-Harcourt and low by Abuja. While the responsibility issues factor is equal to management and the most significant in the overall weightings, it has been established as the least important by Lagos, Abuja and Port-Harcourt and as the most significant by Kaduna and Maiduguri. In addition, the differences in responsibility issues weightings are large compared to the management factor. Although a statistically

significant difference is not established in the policy factor, a disparity exists between the regions due to the large weighting assigned by Abuja, where it is established as the most significant factor. Furthermore, Kaduna has rated policy the least significant with a comparatively lower weighting.

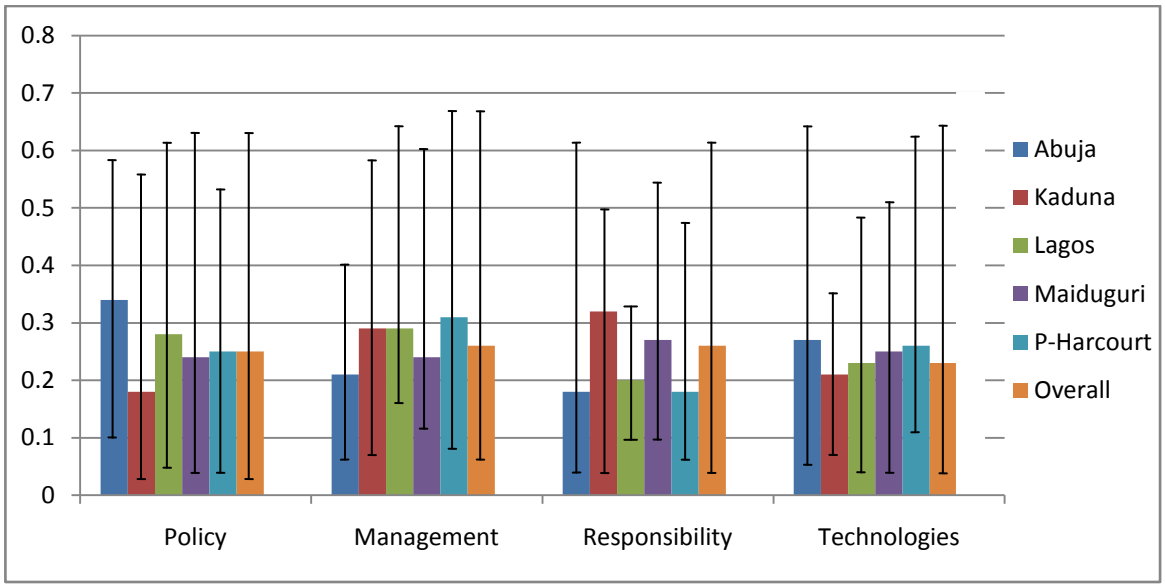


Figure 4.5.2.2 Administrative factors by region

The choice of policy as the most significant factor in Abuja is probably the same as that of the central government as Abuja is the seat of the central government. Furthermore, by evaluating the relatively cleaner environment in Abuja, it can be characterized as having one of the most effective management strategies in Nigeria. This suggests that management has been tackled to some extent and hence its allocation as the least important factor by this region.

4.5.3 Social factors

The weightings assigned to social factors have the widest range of values from 22% to 34%. Health is established as the most significant while the second most significant is stakeholder involvement. Social equity is deemed to be of least importance and service quality the second to the last.

Despite being the first aim of waste management, the health and well-being of humans still suffer from inadequate waste management systems in developing countries (Brunner and Fellner, 2007). An assessment is required to specify a management strategy that will mitigate the adverse effects of improper management on public health. Inclusivity of stakeholders, the second most significant factor, will eliminate one of the major problems of solid waste management, this being lack of ownership. Once stakeholders have an input in decision-making, practices are generally enhanced,

communication is improved and positive attitude towards work is encouraged (Petts, 1994; Adewole, 2009). In addition, understanding and awareness of global and local issues ensues in the course of the decision making process. As ownership is established due to stakeholder involvement, quality of service will automatically improve as obtained from the survey. Furthermore, waste generators are relatively indifferent to equity as long as the service received is of high-quality. Social equity is established of least importance because partial service provision is not a major feature of the solid waste management strategy in Nigeria. With regards inter-generative equity, the waste sites operated are generally open dumps and its effects do not extend over long periods of time in relation to encapsulated landfills (Allen, 2001; Barton *et al*., 2008).

4.5.3.1 Social factors by sector

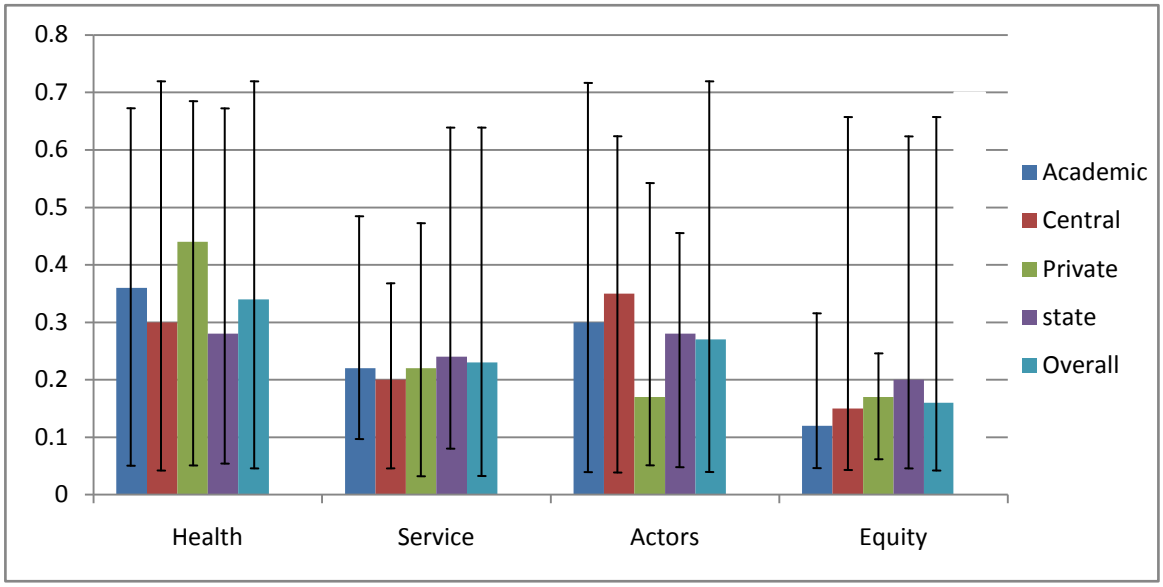


Figure 4.5.3.2 Social factors by sector

The various sectors are generally in agreement with regards to the social factors of the sustainability assessment. Though health is maintained as the most significant factor by all sectors except central government, there are slight differences in the weightings accorded. A particularly high weighting is assigned to health by the private sector and a low weighting to the stakeholders involvement. The formal and informal private sectors have a heightened awareness of health and safety issues due to their role of waste handling on a daily basis compared to the public sector that mainly monitors and enforces standards.

4.5.3.1 Social factors by region

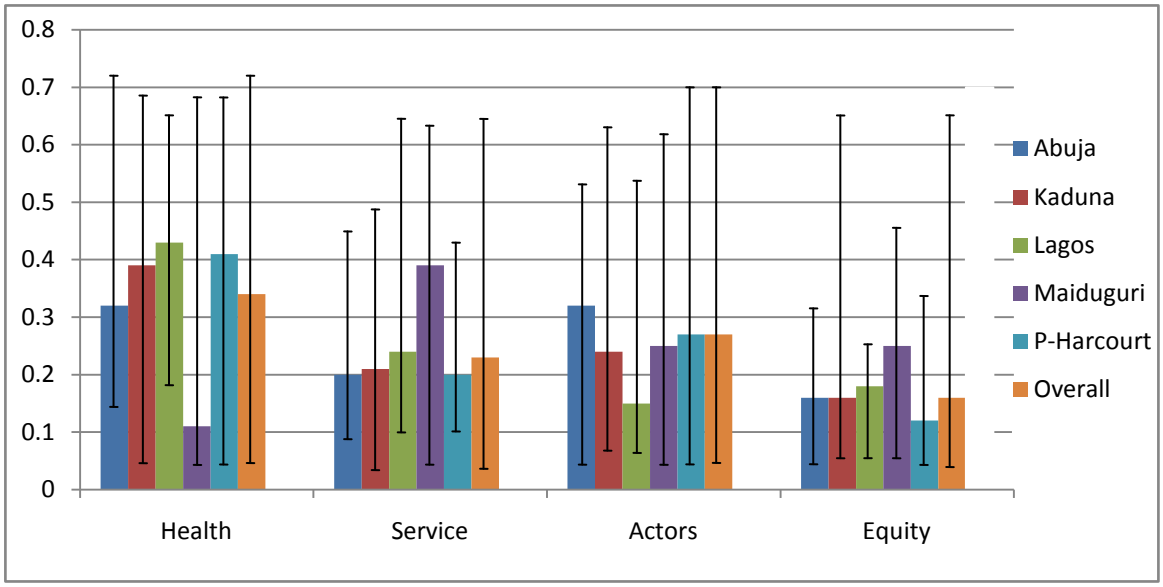


Figure 4.5.3.2 Social factors by region

There is general agreement across the regions regarding the social factors although significant statistical difference is established for the health factor with a p value of 0.04. Four regions have maintained health as the most significant factor while Maiduguri has established it as the least important and with a particularly low weighting. A few variations are prominent in the other social factors despite the lack of statistical differences obtained. The variations are generated mainly by Maiduguri with the most outstanding in the service quality factor established as the most significant factor. From the questionnaires administered, this region suggests high quality of service achieved will reduce problems inherent in the other three social factors.

4.5.4 The economic factors

The two economic factors are established as equal in the overall function with weightings of 50% each. Critical full cost analysis to ascertain revenue required is scarcely performed in Nigeria due to the dominance of public sector service provision for waste treatment and disposal (van de Klundert and Lardinois, 1995). This is in addition to the difficulties in establishing collection cost due to unstructured collection methods by public sector directly normally without funds recovered; formal private sector with direct or indirect fund recovery; and the informal private sector with direct fund recovery.

More job opportunities are created by the informal sector compared to the formal sector. This is driven by the market for recycled materials, lack of formal waste management arrangement for a large population and cheaper and more convenient collection service and (Ogu, 2000; Hayward and Gaskin, 2005; Afon, 2007; Nzeadibe, 2009). In addition, it provides a source of income for the urban poor (Nzeadibe, 2009). However, more prospects for the formal sector are being generated as a result of the recent trend of adopting integrated solid waste management in Nigeria (Hussain, 2008). This in turn suggests more monitoring and enforcement jobs for the public sector.

4.5.4.1 The economic factors by sector

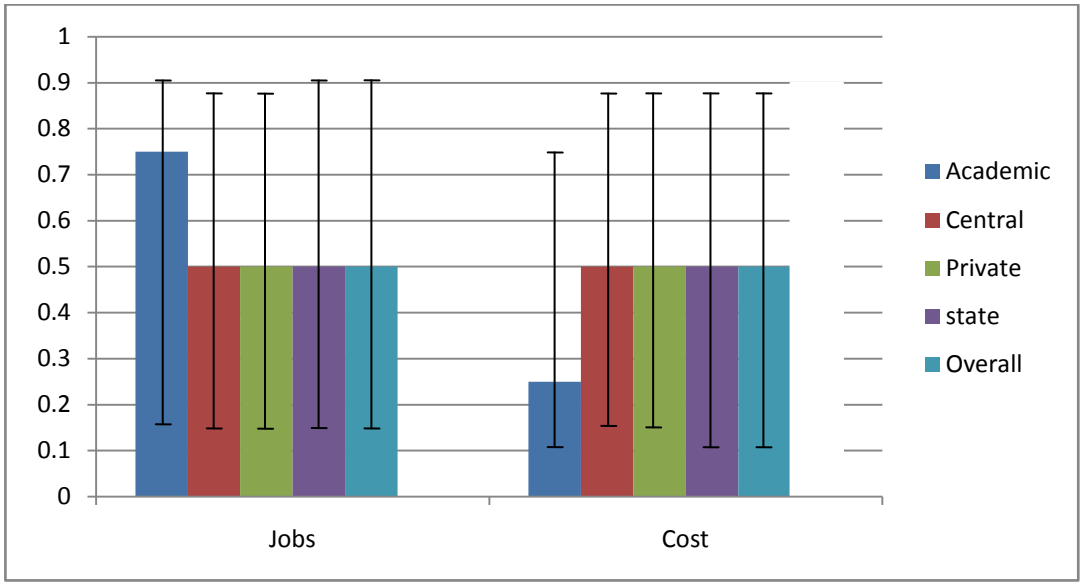


Figure 4.5.4.1 Economic factors by sector

A diagrammatic representation of the similarities and differences within the economic factors is shown in Figures 4.5.4.1 and 4.5.2.2. There is common agreement across sectors regarding economic factors with the two factors assigned equal weightings. However, the academic sector has chosen job creation as the most significant factor with a prominent weighting of 75% compared to cost at 25%. The academic sector suggests private sector participation as a positive development in solid waste management from substantial research carried out in the recent past (Ogu, 2004; Mbuligwe, 2005; Kaseva and Wilson *et al*., 2006; Afon, 2007; Wilson *et al*., 2009). More jobs are created for the private sector due to an increase in private sector participation and especially the informal sector. (Ogu, 2004).

4.5.4.2 The economic factors by region

Similarly general accord between regions, with the notable difference generated by Abuja, that has established job creation as the most significant factor with a weighting of 75%. Despite inherent problems in the management of solid waste in Abuja (Imam *et al*., 2008), it has one of the most successful strategies in the country evidenced by the clean environment. This is achieved by a high rate of private sector participation in addition to greater monitoring and enforcement carried out by the public sector. The activities and involvement of private sector in this region seems more developed compared to the other regions.

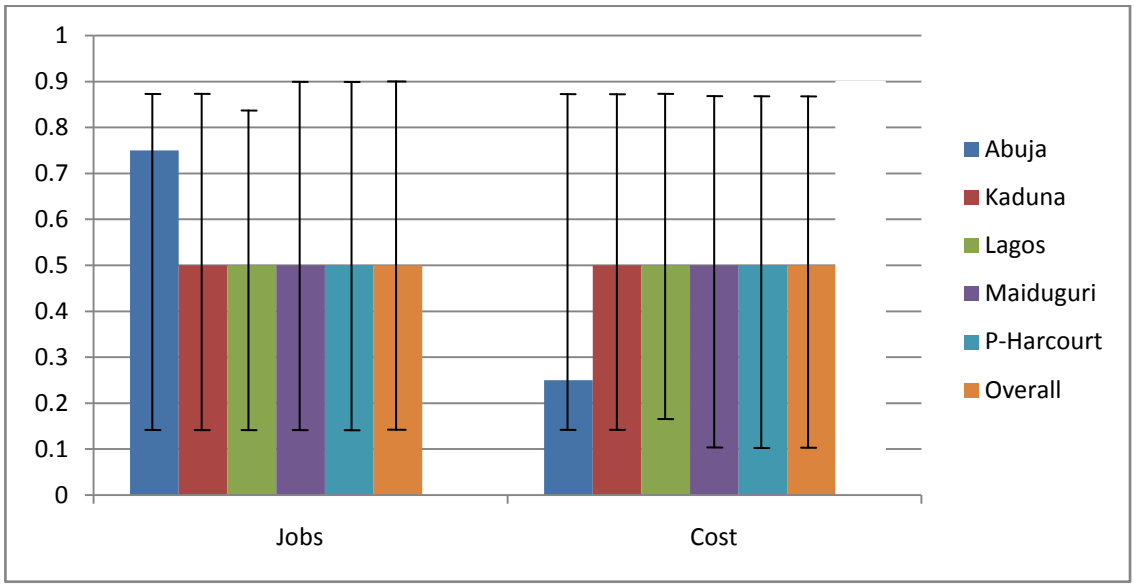


Figure 4.5.4.2 Economic factors by region

4.6 SUMMARY

General support for application of SD as a concept to develop a solid waste management assessment tool is established as well as its breakdown in a three level hierarchy. A need for regrouping indicated by a few respondents reflects the variation of chosen grouped criteria across different studies. The four aspects of sustainability (environmental, administrative, social and economic) were found to have different weightings within a close range of 22-28% with administrative aspect as the most significant despite its absence as a generic principle of sustainable development in the past. This study has established that though close in importance, some aspects and factors have greater priority over others.

Although a common function is determined, the work sectors and regions have differences in the significance accorded to the various aspects and factors. General agreement across sectors and regions are recorded considering the four aspects at the second level of the sustainability

assessment hierarchy. In the third level, statistical differences exist within administrative, social and environmental factors between the regions while it is recorded only in the management factor across sectors. Generally wider variations between weightings were distinguished across regions compared to sectors for the factors and aspects even where statistical significant differences were not recorded. High weightings assigned by regions or sectors generally reflect heightened awareness and problem areas for that region or sector. For instance, the private and state government sector have assigned high weightings to management and responsibility issues due to their responsibility of managing and handling waste directly.

The applicability of the assessment tool generated in this chapter is illustrated in the following section, Chapter five. The sustainability assessment function derived is applied to Kaduna metropolis, a major city in the northern region of Nigeria, to evaluate the solid waste management strategy and establish an index.

5.0 CASE STUDY

5.1 INTRODUCTION

The main aim of this chapter is to evaluate the applicability of the solid waste management assessment tool developed in the previous chapters. To achieve this aim, the solid waste management strategy in Kaduna metropolis is analyzed by adopting a case study methodology. In accordance with the developed model, indicators are specified for each factor, for which scores are assigned, normalised and aggregated to generate an index for the management scheme in Kaduna. The assessment accomplished has shown that waste management strategies can be evaluated with the tool developed in the previous chapters of this study using either desk or field studies.

Although the selection of indicators for sustainability assessment was based on available literature (Desmond, 2006; Den Boer *et al*., 2007), value judgements were made by researcher on the specific indictor chosen to represent a particular factor such as waste minimisation representing resource conservation. This was done due to the difficulty in obtaining reliable data and to ensure the process of assessment remains manageable. Furthermore, indirect methods for quantifying indicators had to be adopted in some cases. The judgements and choices were made based on past practice(s) and studies in the published literature, particularly UNEP (2005), Lang *et al*., (2007) and Bahia (n.d).

5.2 SCOPE OF CASE STUDY

5.2.1 Study area

Kaduna state is the third most populous state in Nigeria after Lagos and Kano (Okunola *et al*., 2007). The state has a total population of six million and a landmass of approximately 48,473 square kilometres (Census, 2006; Lock, 2007; Kaduna State, 2010). Kaduna is the capital of Kaduna state and one of the largest cities in northern Nigeria. The city has a population of 1,563,300, ranked as the fourth most populous after Lagos, Kano and Ibadan (Sanusi, 2010). The city consists of Kaduna north and south, Igabi and Chikun local government areas (Nwude, 2005).

As the former administrative headquarters of the northern region from 1917 to 1967, it is one of the most important political, industrial and economic centres in Nigeria (Ojo, 1995; Okunola *et al*., 2007). The city was founded by Sir Frederick Lugard in the colonial era as a strategic military and administrative base from what was initially a cluster of villages (Lock, 1968). At the time, it was

free of traditional political structure unlike the surrounding cities of Katsina, Zaria and Kano that had emirates with well-defined settlement patterns and trading centres. Water was also available from river Kaduna, a tributary of the river Niger (Lock, 1968). In addition, it is central to the thirteen emirates that made up the protectorate of Northern Nigeria and was served by a railway linking the north to the south-west and with the plan to connect it to the south-east (Lock, 1968).

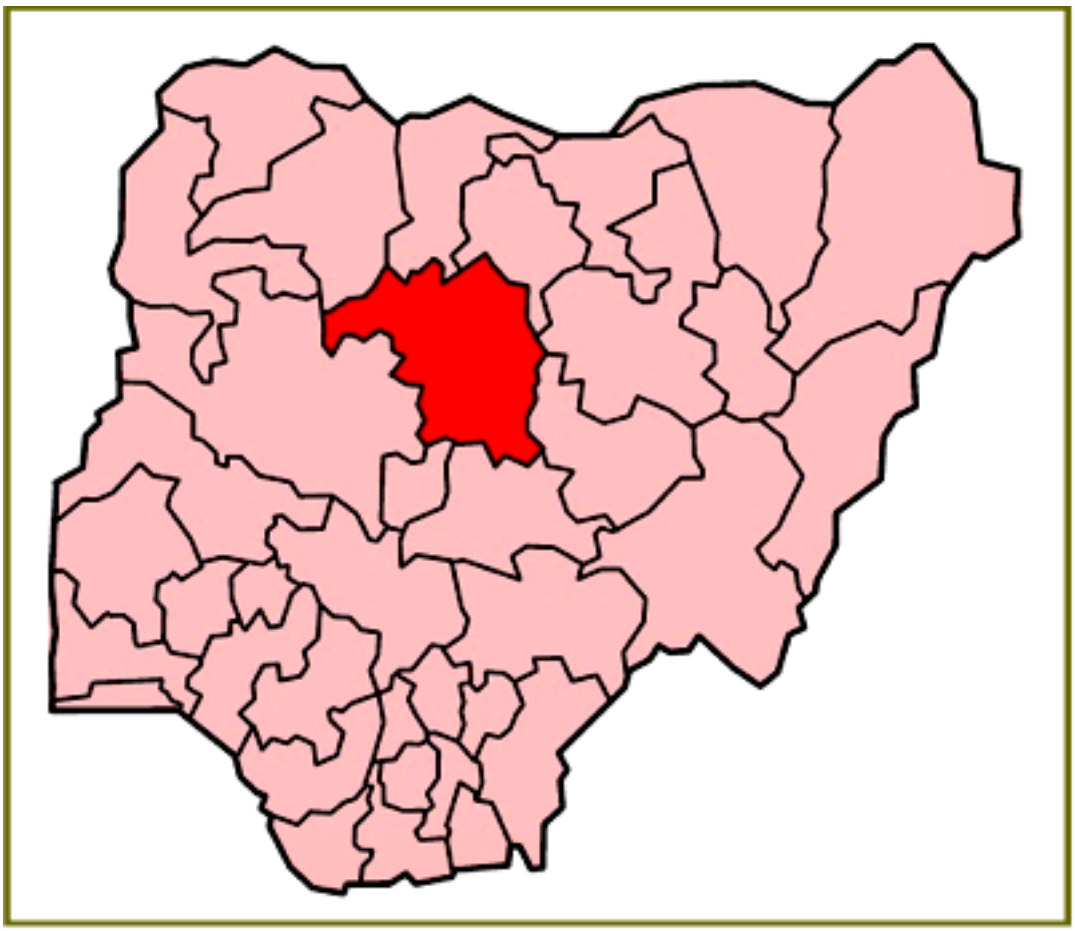


Figure 5.1 Map of Nigeria – Kaduna highlighted (from the Nigerian chamber of Commerce USA)

The state lies in the northern guinea savannah of central Nigeria and has two distinct seasons – the dry and the wet. The dry season extends from November to March and encompasses dust laden harmattan wind, which is dry and cold in the early months and dry and hot towards the end of the season (Ogunsote and Ogunsote, 2002; Adejuwon, 2006). During the rainy season, which begins in the month of April and ends in October, the rain storms are normally violent with thunder and lightning preceded by a driving wind (*Lock, 1968*; Adekunle, 2004; Kaduna State government official site, 2010). Highest temperatures, usually in the month of April, are between 35.0^{o}C to 40.6^{o}C and lowest in January between 7.2^{o} to 12.8^{o} (*Lock, 1968*). An annual average rainfall of 1016mm is recorded for the state which is high compared to the Sahel savannah zones

of the extreme north defined by 600mm of rainfall (Lock, 1968; Adejuwon, 2006). Meanwhile, it is low in comparison to the mangrove forest, rainforest and fresh water swamp zones of the southern parts of the country with mean annual rainfall as high as 3000mm (Adejuwon, 2006).

Figure 5.2 Map of Kaduna (from the Nigerian chamber of Commerce, USA)

Nigeria, including Kaduna, has a potential labour force of approximate 33% with 60% of its population living below poverty line (Ogwueleka, 2009). Despite the generous statutory financial allocations to the three tiers of Government from the sale of crude oil, Nigeria is considered a poor country based on living conditions of the ordinary people (Lock, 2007). The school enrolment rate in Kaduna is between 70-75%, which is higher than the national average of 61.8% with the female rate lower by 10.1% in 2007 (Lock, 2007; World Bank, 2010). Fifty-seven languages are spoken as first languages in the state with the predominant ones being Hausa and English in the capital (Seibert, n.d.). Due to the state of solid waste management and prominence, some cities have been selected for the creation of integrated solid waste management and facility construction - amongst which Kaduna has been chosen (Hussain, 2008; Olaniyan *et al*., 2009).

5.2.2 System boundaries

The system boundary is the interface between the solid waste management system and the environment or other product systems and identifies the start and end of the waste management scheme while defining the unit processes to be studied (Cleary, 2009). Boundaries are influenced by time, space and function (Bjorklund *et al*., 1999; Eriksson *et al*., 2002). The solid waste

management processes typically includes temporary storage, collection, transport, treatment and final disposal; and are considered the core of the system (Den Boer *et al*., 2007; Bjorklund *et al.*, 1999; Cleary, 2009). The beginning of the system is defined by the creation of waste that is the point an item becomes, or is perceived as, valueless and is thrown out, or sent for treatment and includes waste that has been reused and minimised (Cleary, 2009). The end is characterized as the point where value is restored from the waste, transformed into emissions and/or disposed finally (Cleary, 2009).

The functional, geographical and temporal system boundary is defined by household and commercial waste from Kaduna metropolis over a period of one year based on the solid waste management processes outlined in Figure 5.3 (Bjorklund *et al*., 1999; Eriksson *et al*., 2005; Cleary 2009). It includes the emissions into air and water generated during the unit processes from the waste.

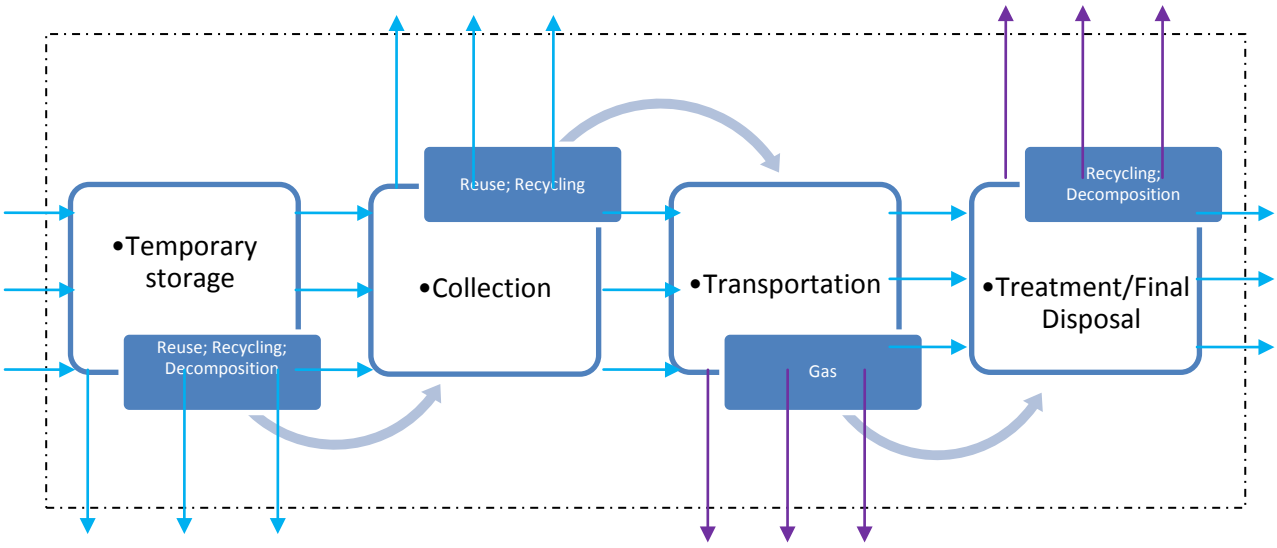


Figure 5.3 Waste management system boundary - Material flow→; Emissions →; Boundary

The period of one year specified allows for the variation of waste generated and its by-products that are influenced by seasons (Al-Yaqout and Hamoda, 2003; Sanphoti *et al*., 2006). Urban centres are especially characterized by heaps of waste on the streets, drains and roads despite having similar waste handling strategies to the rural areas and hence the selection of a city (Ayotamuno and Gobo, 2004; Imam *et al.*, 2008). Household waste is highly heterogeneous and usually has significant fluctuations in quantity and composition among waste sources such that its management is very challenging (Parfitt and Flowerdew, 1997). In addition, household and commercial wastes comprise 89.4% of the total waste generation in Kano adopted for Kaduna

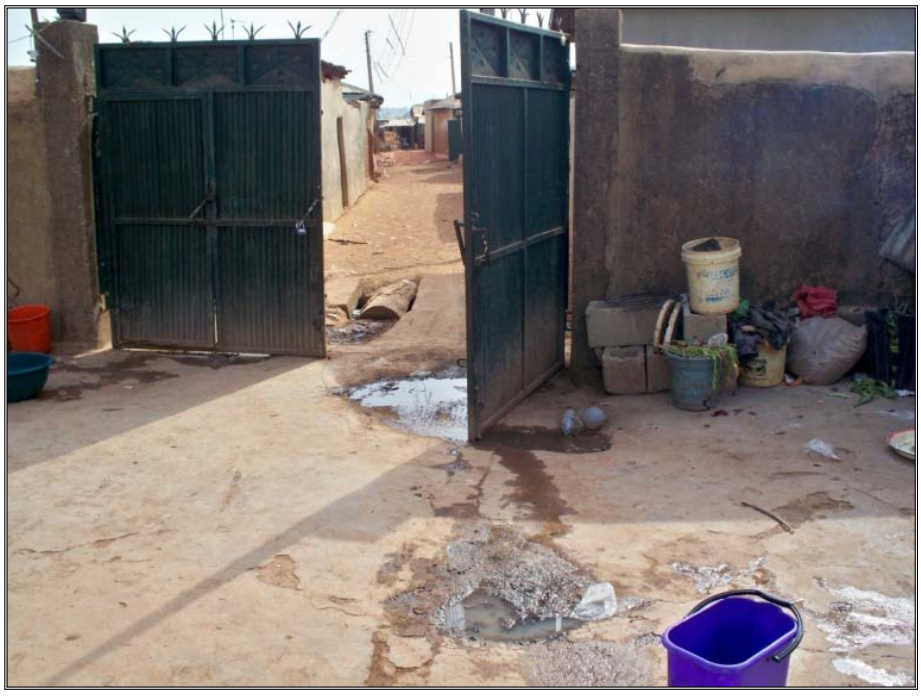
(Nabegu, 2010). Emissions from facilities and vehicles are excluded due to time and resource limitation as well as scarcity of data. Figure 5.2 illustrates an outline of the waste management system boundary defined for this study.

5.2.2.1 Temporary storage

Material going into the temporary storage stage of the system is waste directly from source of generation. The temporary storage in Kaduna encompasses waste dumped at designated or illegal communal disposal sites (shown in Pictures 5.1.1 and 5.1.2) and waste stored within or around households in bins or containers as illustrated in Picture 5.1.3. This accounts for 24% of the total waste generated (Osita and Dauda, 2003; Nabegu, 2010). The communal dumpsites are characterized by waste placed directly on the ground while a few are equipped with large containers (Abdullahi *et al*., 2008; Dauda and Osita 2003; Imam *et al*., 2008). Items are picked from temporary storage points by the informal sector for reuse or recycling. Decomposition begins to occur on the communal disposal sites before the waste is evacuated to a final disposal site. Open burning is also carried out on many communal dumpsites within the city as depicted in picture 5.1.6.

Picture 5.1.1 Temporary storage - waste at communal disposal site (Sani-Katsina, 2010)

Picture 5.1.2 Temporary storage - waste at communal disposal site (Sani-Katsina, 2010)



Picture 5.1.3 Temporary storage within a household in Kaduna (Sani-Katsina, 2010)

5.2.2.2 Collection

Co-mingled waste is collected from temporary storage points by shovelling the waste and (where available) upturning bins or containers into transport vehicles. Items are also picked from the

waste by the collection crew for reuse or recycling. Normally, recyclable items are sold to middlemen or taken to used material shops (Kofoworola, 2007; Imam *et al*., 2008).

5.2.2.3 Transportation

Vehicles are used to transport collected waste to final disposal sites where items for recycling are sometimes selected by the collection crew. Wheel barrows and push carts, as depicted in Pictures 5.1.3 and 5.1.4, are frequently used for moving waste from households to temporary storage areas by informal sector or householders. Fuel based vehicles commonly used in Nigeria for solid waste transportation include pick-ups, tippers and lorries (Imam *et al*., 2008).

Picture 5.1.4 Transporting waste with wheel barrow and push cart (Source, Original)

Picture 5.1.5 Transporting waste with fuel based vehicles (Source, Original)

5.2.2.4 Treatment and final disposal

Picture 5.1.6 Open burning at communal disposal site (Source, Original)

Cities in Nigeria generally lack formal programs for resource recovery, while source separation of waste is practiced by a few (Imam *et al.,* 2008; Babayemi and Dauda, 2010). The informal recycling sector has come in to bridge this gap by recovering material from refuse with a recycling rate of 15% reported in Kano, a city approximately two hours from Kaduna (Abdullahi *et al.,* 2008;

Nzeadibe, 2009; Nabegu 2010). Open burning, to reduce waste, is a common practice performed in backyards, communal dumps and permanent dumpsites (shown in Pictures 5.1.5 and 5.1.6). 6% of the waste ends up at the final disposal sites, which are characterized by large open spaces with perimeter walls and are situated at the outskirts of the city illustrated in Picture 5.1.7 (Dauda and Osita, 2003; Nabegu, 2010). Uncontrolled Emissions of gases and particularly leachate seem to be common occurrences on these sites.

Picture 5.1.7 Open burning at final disposal site (Source, Original)

Picture 5.1.8 Final disposal site at outskirts of Kaduna city, Airport Road (Source, Original)

5.3 DATA INVENTORY

The inventory analysis in this study involves data collection and calculation procedures to quantify relevant inputs and outputs of the solid waste management scheme in Kaduna city. Inventory from significant flows between the environment and waste management, based on the boundary specified, as well as internal material and emissions flow have been established. Data sources include both specific and representative data where specific data is unavailable. In the case of representative data, estimates based on previous studies of situations similar to those of Kaduna have been adopted.

5.3.1 Flow of waste

Total waste generated per year in Kaduna is estimated at 285,300 Kt. This is derived from an estimate of per capita waste generation of 0.50 Kg/day, and a total population of 1,563,300 for Kaduna metropolis (Abdullahi *et al*., 2009; Ogwueleka, 2009). The individual waste generation falls within waste generated in developing countries and similar to other cities in Nigeria such as Makurdi with 0.47 Kg/d and Abuja 0.57 Kg/d (Waste Audit Report, 2004 in Imam *et al*., 2008; Sha'Ato *et al.,* 2007).

A breakdown of the total waste by weight, into component categories, is shown in Table 5.1 and Figure 5.3 with the greatest portion typically food waste for developing countries (Al Khatib *et al.,* 2010; Philippe and Culot, 2009). The breakdown of total waste into the various categories is based on the work of Anake *et al*. (2009), where food waste is 30% by weight, plastics 26% and paper 15%. Metal, similar to paper, is 15% by weight while glass and textiles are 5% each.

Furthermore, the quantities of waste specific to disposal methods are illustrated at the various stages of the management processes in Figure 5.4. The study by Wilson *et al*. (2009) showed that recycling rates of 15 – 20% are achieved by the informal sector in developing countries. With Nigeria categorised as having low but significant recycling rates (Wilson *et al*., 2009; Nzeadibe, 2009), a recycling rate of 15% was adopted. In line with the low recycling rates reported, Maiduguri has recorded a recovery rate of 11.4% including a small percentage of organic waste while UDBN (1998) have estimated 28% for Abuja documented by Imam *et al*. (2008). The 15% recycled waste is divided equally between temporary storage and communal disposal centres because recycling activities in Kaduna is scarcely carried out at the final disposal stage as discovered during the questionnaire survey of this research.

Open dumping of 52% and open burning of 41% are adopted as representative for the waste flow in Kaduna city from the study of Dauda and Osita (2003) in Maiduguri. Open burning and open

dumping are practiced on both the final disposal sites and communal sites (Ayotamuno and Gobo, 2004; Walling *et al*., 2004). According to the same report by Dauda and Osita (2003), only 6% of the waste arrives at the final disposal site while 4% is buried. This is also adopted for the flow shown in Table 5.1 and Figure 5.4.

The flow was generated on the assumption that the composition of the waste does not vary at all stages. Also, wherever a disposal method is encountered at different stages (such as communal and final disposal stages), the quantity of the waste disposed in that manner is shared equally between the stages. Once the 6% final disposed waste and 15% recycled component is taken out, the balance is divided based on the percentages of open burning and dumping between the household and communal disposal (temporary storage) stages before it is transported to the final disposal point. While 6% of the total waste is deposited in the final disposal site, approximately 2.3% of the waste is unaccounted for and is added to the waste at the final disposal for the purposes of this flow diagram.

The data used in establishing the waste flow from journal articles and conference papers, though scarce, is generally reliable. However, the data is not strictly for Kaduna metropolis, which would have been ideal. The data was sourced across some major cities particularly Maiduguri and Port Harcourt. Waste composition by weight was obtained from the work of Anake *et al*., 2009 carried out in Kaduna.

Table 5.1 Material flow

Waste type	Weight (%)	Temporary storage (Households - Kt)	Recovered material and reduced waste (A)	Temporary storage (Communal dumps- Kt)	Recovered material and reduced waste (C)	Final disposal (D) (6%)
Food waste, F_w	30	85,590		39,216		7,163
Paper , P_w	15	42,795		19,607		3,582
Metal M_w	15	42,795		19,607		3,582
Glass, G_w	5	14,265		6,536		1,194
Textiles, T_w	5	14,265		6,536		1,194
Plastic, C_w	26	74,178		33,984		6,208
Others, O_w	4	11,412		5,228		955
Reuse + Recycling			21,398 (7.5%)		21,398 (7.5%)	
Burning, Bg			46,204		46,204	
Burying, Br			4,508		4,508	
Open dumping, Od			58,601		58,601	
Total	100	285,300	130,711	154,589	130,711	17,118
Residual			154,589			

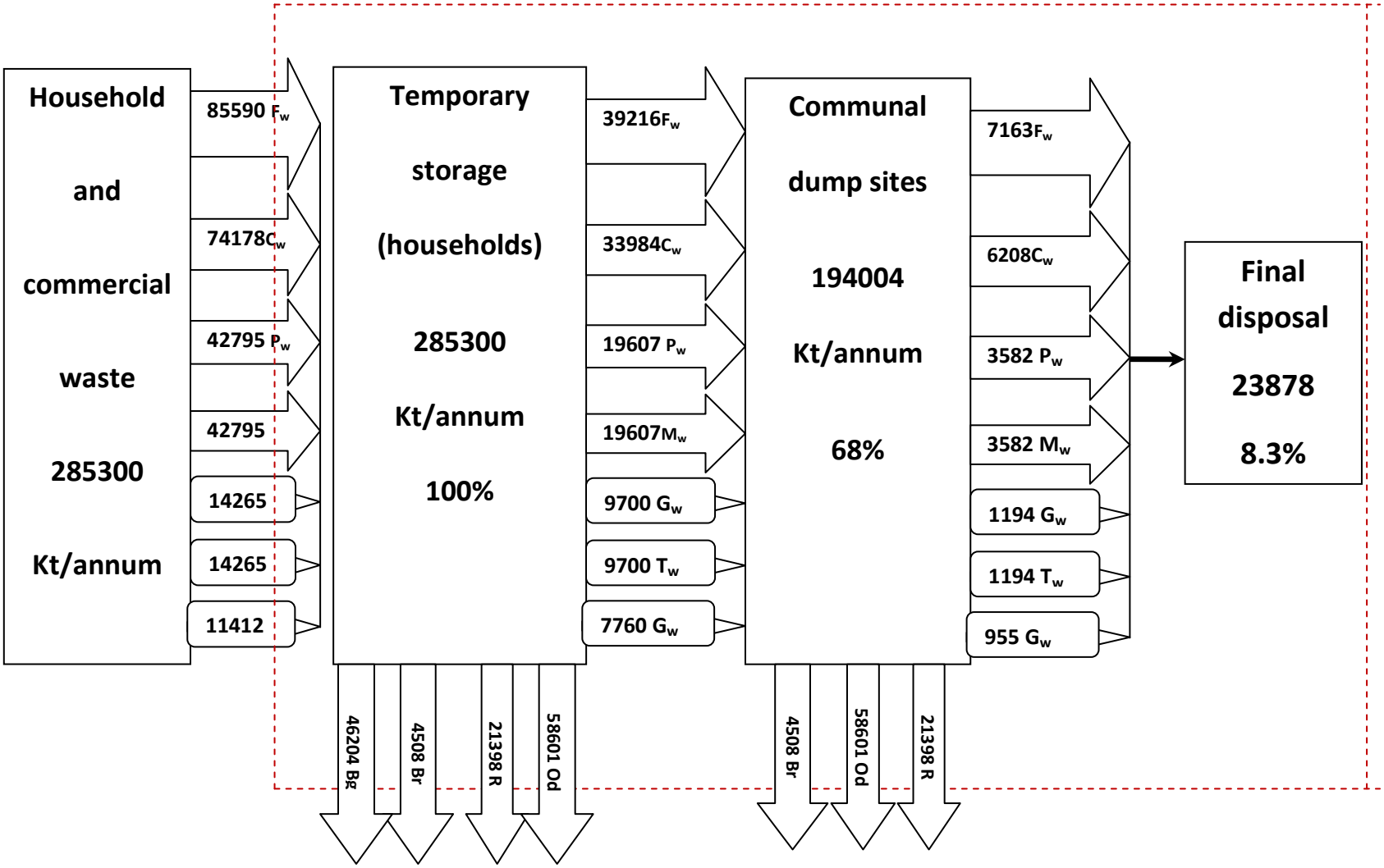


Figure 5.4 Flow of waste (See Table 5.1 for waste types)

System boundary - (All units are in Kt/annum)

5.3.2 Availability of data

Generally, assessment of sustainability has been found to be complex and the amount of data required to quantify sustainability indicators enormous (Ashley *et al*., 2005). Securing such data in Nigeria similar to many developing countries is a challenge due to scarcity of reliable data. Baseline data is hardly available from the local authorities' while the available data from peer-reviewed papers and articles are generally for a relatively short period based on the type of study (Bartone, 1990; Agunwamba, 1998; Kofoworola, 2007). PhD studies usually run for three to six years while data collection for some projects last for as brief as a year or less. Furthermore, a substantial amount of the available data has not been peer reviewed.

5.4 INDICATORS

The indicators applied to obtain an index for the management strategy in Kaduna are derivatives of the factors specified in the solid waste management assessment tool in Section 4.5. They are the measurable units at the fourth stage of the hierarchy. The basic purpose of indices is to allow assessment across time or space for decision making, policy progress evaluation, performance monitoring and benchmarking comparisons (Ebert and Welsch, 2004; Zhou *et al.,* 2007). In addition, it aids peoples' understanding of actual levels of environmental quality (Kang *et al.,* 2002).

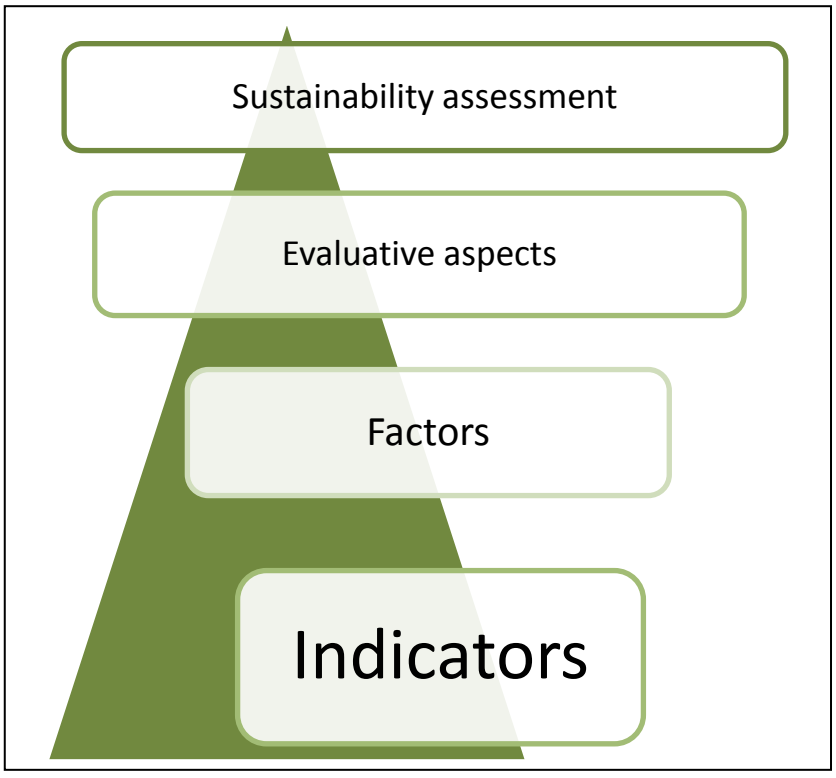


Figure 5.5 Sustainability assessment hierarchy model

5.4.1 Developing the index

Developing the index is a multi-level process classified into theoretical, operational and goal levels as described by Zhou *et al.* (2007), which is in concurrence with other studies carried out by Kang *et al.* (2002) and Jha and Murthy (2002) (See figure 5.5). The first stage was defining the environmental system as solid waste management. Selection of appropriate variables and classification was based on the principles of sustainability in relation to waste management, which identified four evaluative criteria – administrative; social; economical and environmental aspects. These are further sub-divided into thirteen factors and finally thirteen indicators are derived for the purpose of this study. The goal is to move the existing strategy towards enhanced performance and sustainability.

Table 5.2 Indicators

Environmental indicators	**Administrative indicators**	**Social indicators**	**Economic indicators**
$I_{1,1}$ Smoke (PM_{10})	$J_{1,1}$ Policy quality	$K_{1,1}$ Exposure to waste	$L_{1,1}$ Job creation
$I_{2,1}$ Leachate	$J_{2,1}$ Waste collection	$K_{2,1}$ Stakeholders satisfaction	$L_{2,1}$ Cost recovery
$I_{3,1}$ Waste minimisation	$J_{3,1}$ Information dissemination	$K_{3,1}$ Stakeholders awareness	
	$J_{4,1}$ Conveyance fleet	$K_{4,1}$ Intra- and inter-generational equity	

The indicators selected were normalised and made commensurable before being aggregated for the index to be meaningful (Ebert and Welsch, 2004). Normalising the various indicators and aggregating them is shown in Sections 5.5.1 to 5.6.5. A rigorous connection has been established between sustainability and the indicators through the breakdown of the concept as illustrated by the hierarchical diagram of Figure 4.1 (Section 4.3) and the sustainability function of Equation 1 (Section 4.3.1) (Bohringeer and Jochem, 2007). The data used was relatively available and practical to measure and record. This is demonstrated in Section 5.4 and 5.6 where the indicators and results of the evaluation are presented. In addition, an attempt was made to clearly define the indicators for clarity and understanding. The process established in the selection of indicators included evaluating indicators commonly specified by other studies for assessing environmental systems particularly waste management schemes (Desmond n.d.; Klundert and Lardinois, 1995; Bosshard, 2000; Walmsley, 2002; den Boer *et al*., 2007; Salhofer *et al*., 2007). The main studies used were carried out by Bahia (n.d), van de Klundert and Anschutz (2001), UNEP (2005) and Lang *et al*. (2007). Due to inadequate data, representative indicators were used as suggested by the report of Bossel (2001) by using a

variable that has relatively reliable information that is characteristic of the whole complex situation. Consistent baseline data such as waste generated per household and number of employees per ton of collected or disposed waste is hardly available. This complexity is further enhanced by the presence of the informal sector in the system; who are characterised unregistered and unregulated waste service provision. Justification for the individual indicators selected is shown in Sections 5.5.1 to 5.5.4.

5.5 METHODS

Individual methods were employed to assess each of the various indicators identified. Both selection of indicators and approaches for their scoring and normalising were mostly obtained from the studies of Bahia (n.d.), UNEP (2005) and Lang *et al*. (2007). However, a general approach of defining scores is employed throughout this section where 0 defines the worst case scenario and 100 the most effective similar to Lang *et al*. (2007). However the study carried out by Lang *et al*. (2007) defines the most effective as 0 and 100 as the least effective case. The 100 maximum score points specified for each indicator maintains uniformity and is consistent with the work of UNEP (2005).

Equation 1

$$SI = 0.065I_{1i} + 0.103I_{2i} + 0.103I_{3i} + 0.07J_{1i} + 0.073J_{2i} + 0.073J_{3i} + 0.064J_{4i} + 0.078K_{1i} + 0.053K_{2i} + 0.062K_{3i} + 0.037K_{4i} + 0.11L_{1i} + 0.11L_{1i}$$

The sustainability function (Equation 1) was used to establish the index for Kaduna metropolis by applying established scores to the indicators that were generated from available literature. A factor is represented by a single indicator to maintain uniformity across assessment factors while ensuring all aspects are appraised. The scores determined for each indicator was inserted into the SI function and aggregated to derive the sustainability index for the case study.

5.5.1 Environmental Indicators (I)

The environmental factors - air quality, water quality and resource conservation, are represented by presence of particulate matter, leachate availability and waste minimization.

5.5.1.2 Air Quality Indicators – Particulate Matter, PM_{10} ($I_{1,1}$)

Air pollutants in urban areas are commonly employed as air quality environment indicators (Lang *et al*., 2007; Kierstead and Leach, 2008). This indicator determines the presence of particulate matter in the atmosphere similar to the proposal of Bahia (n.d.). A major concern in Nigeria is the smoke from open burning of solid waste, which is the second predominant waste disposal method in Kaduna similar to other Nigerian cities and is an indication of the presence of particulate matter (PM_{10}) (Dauda and Osita, 2003; Ogwueleka, 2009). PM_{10} is one of the most common air pollution entities to have significant impacts on the environment (Sapkota *et al*., 2010). The scale for this indicator is defined by:

- Open burning on both final and communal disposal sites = 0
- Open burning on final disposal sites but absent on communal disposal sites = 50
- Open burning on communal disposal sites but absent on final disposal sites = 50
- Open burning absent on both final and communal disposal sites = 100

5.5.1.2 Water Quality Indicator – Leachate ($I_{2,1}$)

Water quality has been identified as an indicator of environmental sustainability (Bahia, n.d; Hammond *et al*., 1995; Lang *et al*., 2007). Generally, quality of water is adversely affected by leachate from solid waste. A study by Loizidou and Kapetanios (1993) found that leachate from solid waste affect underground water of surrounding area up to a distance of 3km by testing its physical and chemical parameters. Another study by Mor *et al*. (2006), with similar results of high concentrations of physical and chemical parameters, sampled ground water within 1.5km of a landfill site. A leachate system is usually an affective means controlling leachate migration (and therefore water contamination) for all types of landfill strategies (Allen, 2001).

The scale for this indicator is therefore defined by:

- Existence of leachate without barrier and without collection system = 0
- Existence of leachate without barrier but with collection system = 50
- Existence of leachate with barrier but without collection system = 50
- Existence of leachate with barrier and collection system = 100

5.5.1.3 Resource conservation indicator – Waste Minimisation ($I_{3,1}$)

The indicator for resource conservation, established from UNEP (2005) and in line with the study of Klundert and Anschutz, 2001, employed for the evaluation is waste reduction initiative(s) and the implementation of resource recovery programs and facilities. Recycling in

developing countries has been found to be a component of sustainable solid waste management (Troschinetz and Mihelcic, 2009). While resource recovery activities are managed by both formal and informal sector in some developing countries such as Jordan (Abu Qdais, 2006), it is managed solely by the informal sector in others such as Nigeria (Afon, 2007; Wilson *et al*., 2009). However, the need to establish a strategy that highlights waste minimisation to conserve resources and avert materials from the waste stream cannot be overemphasized as outlined in section 2.4.1.2.

The scale for this indicator is defined by:

- No waste reduction initiatives adopted and no implementation of resource recovery programs and facilities = 0
- Adoption of waste reduction initiatives but no implementation of resource recovery programs and facilities =50
- Adoption of waste reduction initiatives and implementation of resource recovery programs and facilities = 100

5.5.2 Administrative Indicators (J)

The administrative indicators include quality of policy representing the policy factor; collection rate and coverage for management factor; information distribution for the responsibility issue category and adequacy of conveyance fleet to local conditions adopted to assess technologies.

5.5.1.3 Policy Indicator – Policy quality ($J_{1,1}$)

As mentioned in section 2.4.2.1, the government has the responsibility of providing a waste management system appropriate to local circumstances and international treaties by bringing together its many different but related facets (Rushbrook and Finnecy, 1988). One of the main features of the system structure is a national policy to achieve the objectives of waste management. Once the policy is developed, a group of issues must be addressed to ensure the objectives are met and legislation for ensuring policy implementation must be produced.

To assess the policy in Kaduna, the key issues adopted for this indicator are proposed by UNEP (2005) and include policies on environmental protection, solid waste management, waste minimization, resources recovery, landfill disposal and financial sustainability in line with the study of Klundert and Anschurtz (2001). The effectiveness of the policy also includes the existence of an agency or department created for managing solid waste as outlined by UNEP (2005). To address the issues outlined, the scale is defined by:

- None of the outlined issues are addressed with no department or agency set up to manage solid waste = 0
- One out of five outlined issues addressed with no department or agency set up to manage solid waste = 10
- Two out of five outlined issues addressed with no department or agency set up to manage solid waste = 20
- Three out five outlined issues addressed with no department or agency set up to manage solid waste = 30
- Four out of five outlined issues addressed with no department or agency set up to manage solid waste = 40
- All outlined issues addressed with no department or agency set up to manage solid waste = 50
- None of the outlined issues are addressed with a department or an agency set up to manage solid waste = 50
- One out of five outlined issues addressed with a department or an agency set up to manage solid waste = 60
- Two out of five issues addressed with a department or an agency set up to manage solid waste = 70
- Three out of five outlined issues addressed with a department or an agency set up to manage solid waste = 80
- Four out of five issues addressed with a department or an agency set up to manage solid waste = 90
- All outlined issues addressed with a department or an agency set up to manage solid waste = 100

5.5.2.2 Management Indicator – Waste collection ($J_{2,1}$)

This is an indicator that evaluates the general day to day activities of the agency or department (Klundert *et al*., 2001). Effective management is linked directly to the provision of infrastructure and programs to support waste disposal and treatment options such as reuse and recycling (Desmond, 2006). The percentage of total population that receives frequent and regular service is used to determine the functionality of the regulatory agency as proposed by Bahia (n.d); Anschutz and Klundert (2001) and UNEP (2005). In addition, 77-99% of solid waste management expenditure is spent on collection in Nigerian cities (Ogwueleka, 2003). This is similar to the 70-80% of the total waste management cost allocated to collection and transportation reported by Imam *et al*. (2008). The scale for this indicator is defined by:

- Total population without waste collection service = 0
- A percentage of the population with irregular collection service = 25
- A percentage of the population with regular collection service = 50
- Total population with irregular waste collection service = 75
- Total population with consistent collection service = 100

5.5.2.3 Responsibility Issues Indicator – Information dissemination ($J_{3,1}$)

Information dissemination of waste management options and issues is employed as an indicator for responsibility issues. The spread of information to individuals, groups and organizations at the household, communities and city levels is essential to creating awareness and therefore to an effective solid waste management strategy (Hayward and Gaskin, 2005; Petts, 2000). Solid waste management programs generated by the authorities are an indication of information distribution in the city. Common means of distributing information in Nigeria involves seminars, conferences and media with a general lack of follow-up after the initial conferences, workshops and seminars (Imam *et al*., 2008; Nabegu, 2010; Zavodska and Uhuo, 2010). While the method is appropriate for certain groups such as the highly educated, the waste management sector includes the informal sector as well as general public, who may not have the sophistication to understand conferences. The scale for the responsibility issue indicator is therefore defined by:

- Method of information distribution unsuitable to both formal and informal sectors = 0
- Method of information distribution unsuitable to formal sector but appropriate for informal sector = 50
- Method of information distribution suitable to formal sector but inappropriate for informal sector = 50
- Method of information distribution suitable to both informal and informal sectors = 100

5.5.2.4 Technologies Indicator – Breakdown of conveyance fleet ($J_{4.1}$)

The indicator employed to assess the technical sustainability of the solid waste management scheme in Kaduna metropolis is adequacy of the conveyance fleet to local conditions as proposed by Bahia (n.d). The breakdown of vehicles is employed as an indication of adequacy. The waste conveyance vehicles commonly used in Kaduna similar to other Nigerian cities are loaders, tippers, carts and wheel-barrows (Imam *et al*., 2008; Wilson *et al*., 2009). There is a clear distinction between the conveyance vehicles where long distances are covered by fuel

based vehicles such as loaders while short distances are covered by non-fuel based vehicles such as carts. As such, they are referred to as fuel and non-fuel based vehicles for the purpose of this study. The fuel based vehicles are used to transport large quantities of waste from the communal sites to final disposal sites while the non-fuel based transport small amounts from households to the communal disposal sites (Afon, 2007; Imam *et al*., 2008). This is because the final sites are generally situated at considerable distances away from the communal disposal sites and dwellings while the communal disposal sites are usually near residences. The indicator is defined by:

- Frequent breakdown of both fuel and non-fuel based vehicles = 0
- Frequent breakdown of fuel based vehicles while non-fuel based vehicles are in frequent operation = 50
- Frequent breakdown of non-fuel based vehicles while fuel based vehicles are in frequent operation = 50
- Both fuel and non-fuel based vehicles are in frequent operation = 100

5.5.3 Social Indicator (K)

Indicators of health are amongst the social indicators that are hard to quantity and often not addressed despite their importance (Balkema *et al*., 2002). Other social indicators include satisfaction of users regarding the strategy in place, consistency of service, awareness and participation of all stakeholders and fairness of the strategy within this generation and between generations.

5.5.3.1 Health Indicator – Exposure to Waste ($K_{1.1}$)

"Inadequate environmental sanitation in many cities is a major cause of diseases and is a drain on the economy by way of lost workdays, cost of treatment and cleanup activities" (Joseph, 2006 pg 863). Health is evaluated by the exposure of people in Kaduna city to visual intrusion and pollution by solid waste as an indicator proposed in the report of Bahia (n.d.). In the same report, a distance of 500m is proposed as a safe distance between dwellings and solid waste sites. Direct contact with waste is generally a function of waste dumps in public spaces or dwellings situated close to uncontrolled waste facilities. The health indicator is defined by:

- Uncontrolled temporary and final disposal sites near dwellings (<500m) = 0
- Uncontrolled temporary disposal sites near dwellings (<500m) with uncontrolled final disposal sites away from dwellings (>500m) or controlled final disposal sites near dwellings = 50

- Controlled temporary disposal points near dwellings (<500m) with uncontrolled final disposal points away from dwellings (>500m) = 100
- Uncontrolled temporary and final disposal points away from dwellings (>500m) or Controlled temporary and final disposal points = 100

5.5.3.2 Quality of Service - Stakeholder Satisfaction ($K_{2,1}$)

The indicator selected to illustrate the sustainability of service quality is the satisfaction of users regarding the existing strategy in Kaduna. The stakeholder's perception of satisfaction has been used to determine service quality performance (Hung *et al*., 2003). Questionnaires are commonly used to gauge satisfaction of customers as adopted by Afon (2007) to determine the satisfaction of users regarding to solid waste management strategy (Hung *et al*., 2003). Service quality regarded as a composite of various attributes is usually determined using criteria such as convenience and reliability (Tsaur *et al*., 2002). This was also employed by Afon (2007) in determining an index of satisfaction for Lagos city that has a similar waste management arrangement to other Nigeria cities. The reliability of the data adopted for resident's satisfaction (obtained from a journal article) is sound due to the methodology employed in the study. Satisfaction was determined via the residents satisfaction index (RSI) where seven attributes of the waste managers were rated by the respondents using likert's scale. The attributes included service availability; cost of service and politeness of waste managers. In total, 301 respondents were questioned in the study of Afon (2007). The scale for stakeholder satisfaction is defined by:

- No satisfaction at all = 0
- Partial satisfaction where the score is determined based on the study of Afon (2007). The score = percentage of the index = (Y x 100) (where Y is the index)
- Total satisfaction for all criteria = 100

5.5.3.3 Stakeholder Participation – Stakeholder's Awareness ($K_{3.1}$)

Identified as a major condition for pro-environmental behaviour, awareness of waste management issues indicates positive involvement of stakeholders towards sustainable management of solid waste (Petts, 2000; Williams and Kelly, 2003; Mbeng *et al*., 2009; Babalola *et al*., 2010). Questionnaires, as adopted by Babayemi and Dauda (2009), are often used to elicit information from stakeholders' (Reddy and Painuly, 2001; Himes, 2007). The score for this indicator is recorded directly from the study of Babayemi and Dauda (2009). The study involved 201 respondents with varying educational levels and ages. The attribute employed in establishing the awareness of the respondents include direct questions on the

awareness of waste management regulations, waste collection services and waste disposal options in the region. The reliability of the data is relatively low; however papers with similar information are scarce.

5.5.3.4 Social Equity Indicator – Inter- and intra-generational equity ($K_{4.1}$)

This social indicator is represented by exposure of the future generations to disposed waste and proximity of waste management sites to any particular socio-economic group. Existing literature has identified exposure of the future generations to disposed waste in accordance with the study of Lang *et al*. (2007) and proximity of waste management sites to any particular socio-economic group as reported Lang *et al*. (2007) and Bahia (n.d) as an appropriate social equity indicator. The containment approach to landfill management is a key means of exposing future generations to the negative effects of past waste. The containment strategy encapsulates waste, which inhibits its degradation and therefore prolongs its stabilization to an inert state for several decades (Allen, 2001). Social equity enhances the support and participation of the local community, which is viewed as a precondition for sustainability (Chung and Lo, 2003). The scale similar to the approach of Lang *et al.* (2007) for this indicator is defined by:

- Waste management sites located near particular socio-economic group and decomposable waste fully contained = 0
- Waste management sites located near particular socio-economic group and decomposable waste allowed to decompose = 50
- Waste management sites not located near particular socio-economic group and decomposable waste fully contained = 50
- Waste management sites not located near particular socio-economic group and decomposable waste allowed to decompose = 100

5.5.4 Economic Indicators (L)

The economic indicators consist of availability of jobs that provide means of livelihood and a comparison between the waste management total cost evaluation of the private sector and the public sector.

5.5.4.1 Employment Indicator – Job Creation ($L_{1.1}$)

Employment creation is commonly used to assess the economic sustainability of systems with the condition that labour is remunerated (Hanegraaf *et al*., 1998; Domac *et al*., 2005). The

waste authorities and formal contractors generally provide collection and disposal services strictly, while the informal sector includes the services of resource recovery. Due to the distinction between formal and informal sector service provision, the scale is defined by:

- No Employment created for both formal and informal sector = 0
- No employment created for formal sector but created for informal sector with wages less than minimum wage = 25
- No employment created for informal sector but created for formal sector with wages less than minimum wage = 25
- No employment created for formal sector but created for informal sector with wages up to minimum wage = 50
- No employment created for informal sector but created for formal sector with wages up to minimum wage = 50
- Employment created for both formal and informal sectors with wages up to minimum wage for formal sector but less than minimum wage for informal sector = 75
- Employment created for both formal and informal sector with wages less than minimum wage for formal sector but up to minimum wage for informal sector = 75
- Employment created for both formal and informal sector with wages up to minimum wage = 100

5.5.4.2 Total cost – Cost recovery ($L_{2.1}$)

The indicator used to establish the sustainability of the strategy is the total cost analysis. The total cost is essential to appraise cost effectiveness of a system, which has been used in previous studies to establish economic sustainability (Balkema *et al*., 2002; Den Boer *et al*., 2007). The methodology adopted assumes that the private sector organizations, which are profit making ventures, must have captured the total cost of providing the waste management service (Balkema *et al*., 2002). Meanwhile, the main revenue for waste management of the authorities is the government subvention and may not have captured the total cost effectively. This is because the public sector is associated with ineffective and inefficient service provision which suggests higher operational and maintenance cost as well little recovery from service beneficiaries (Bello and Szymanski, 1996; Reeves and Barrow, 2000; Ogu 2000). Subsidies or grants per person can be used to aid assessment as proposed by Den Boer *et al*. (2007). As long as the subsidies cover the cost of managing solid waste, it is considered economically sustainable (Den Boer *et al*. 2007). User charges and general government revenues are commonly used to recover the cost of solid waste management operations (Bartone et al., 1990). The user charges are adopted in this study due to lack of forthcoming data from the

government organisations. The cost allocated by the waste authorities is compared to the charges of the private firms with the scale defined as:

- Cost allocated by authorities less than private sector charge and no private sector participation = 0
- Cost allocated by authorities less than private sector charge but with private sector participation = 50
- Cost allocated by authorities up to charges of private sector but no private sector participation = 50
- Cost allocated by authorities up to charges of private sector and private sector participation = 100

5.6 RESULTS AND DISCUSSION OF THE EVALUATION OF KADUNA CITY SOLID WASTE MANAGEMENT SCHEME

The result obtained for each indicator is presented in Tables 5.3.1 – 5.3.4 including a discussion of the results covered in the Sections 5.6.1 to 5.6.4.

5.6.1 The Environmental Indicators

The environmental indicators have the lowest scores amongst the four aspects of solid waste management assessment. The highest score of 50 points in this category was attained by the resource conservation indicator, waste reduction. The generally low scores are a result of all the final waste disposal sites that are lacking barriers and leachate collection systems (Dauda and Osita, 2003; Imam *et al*., 2008; Abdullahi *et al*., 2008; Nabegu, 2010). This was confirmed from the staff of Kaduna environmental protection authority (KEPA).

Table 5.3.1 Environmental indicators

Factor	Indicator	Final score
Air quality- $I_{1,1}$	Smoke, PM_{10}	**0**
Water quality– $I_{2,1}$	Leachate	**0**
Resource conservation– $I_{3,1}$	Waste reduction	**50**

5.6.1.2 Air Quality Indicator – Particulate Matter ($I_{1.1}$)

The score allocated to particulate matter is 0 as the emission of particulate matter into the atmosphere has been established. Therefore the score for air quality indicator is low as a result

of smoke from open burning, which is the second major method of waste disposal in Nigeria (Walling *et al*., 2004).

Air quality = 0

5.6.1.2 Water Quality Indicator – Leachate ($I_{2.1}$)

The water quality indicator has been assigned a score of 0 as leachate produced from solid waste is not controlled and has no collection and treatment system in place. This applies to all landfill sites in Kaduna due to the absence of barriers in the landfills as confirmed by the staff of Kaduna environmental protection authority (KEPA) in 2009. The communal and final disposal sites in Kaduna as outlined in sections 5.2.2.1 and 5.2.2.4 are characterized by open spaces where waste is generally place directly on the ground or deposited into shallow holes (Dauda and Osita, 2003; Imam *et al*., 2008; Abdullahi *et al*., 2008; Nabegu, 2010). While the threat of leachate to the final disposal sites is mitigated due to its distance from settlements, the communal sites located all over the city (Hussaini, 2008) are a risk to dwellers due to high proximity. It therefore hinders sustainability of the solid waste management scheme.

Water quality = 0

5.6.1.3 Resource conservation Indicator – Waste reduction ($I_{3.1}$)

The score attained by the resource conservation indicator is 50. While the authorities do not have material recovery programmes and facilities established in Kaduna similar to other cities in Nigeria, the waste generators in conjunction with the informal sector are engaged with waste reduction (Kofoworola, 2007; Wilson *et al*., 2009). As stated in section 2.2.4, the waste reduction effort in Nigeria has been found to compare well with many developed countries (Wilson *et al*., 2009). Waste minimization in Kaduna is generally driven by the scarcity of sources that encourages people to make optimum use of available materials. This is addition to the inadequacy of the formal waste collection and the relatively good wages earned from selling used material for reuse or recycling compared to the state minimum wages (Nwaka, 2005; Nzeadibe and Ajaero, 2010).

Resource conservation = 50

5.6.1 The Administrative Indicators

The administrative indicators attained scores generally, with a notably high score recorded for the policy indicator, due to existence of regulations and an agency or department to handle solid waste.

Table 5.3.2 Administrative indicators

Factor	Indicator	Final score
Policy - $J_{1,1}$	Existence of regulations and agency or department	**80**
Management – $J_{2,1}$	Collection service	**25**
Responsibility issues – $J_{3,1}$	Information Dissemination	**50**
Technologies – $J_{4,1}$	Conveyance fleet adequate to local conditions	**50**

5.6.2.1 Policy Indicator – Existence of regulations and agency or department

The policy indicator was assigned a score of 80 points. This is because three out of the five outlined issues in section 5.5.1.3 were addressed in the regulations as shown in the Kaduna State environmental laws and edicts document of Appendix 3. Furthermore, the state has two existing environmental agencies that have solid waste management departments – Kaduna environmental protection agency (KEPA) (Hussaini, 2008) and Kaduna State ministry of environment and natural resources both situated within the city. Although many guidelines are available, they are generally vague and lack adequate details especially for household and commercial waste (Imam *et al*., 2008).

Policy = 80

5.6.2.2 Management Indicator – Collection service ($J_{2.1}$)

The management indicator based on collection regularity attained a score of 25. This is as a result of irregular collection of solid waste and only a percentage of the population having collection service in Kaduna similar to other Nigerian cities. The problem of inconsistent collection has led to the existence of fourteen notorious dumps in the metropolis (Hussaini, 2008). In other cities such as Benin, only 6% of the population had access to regular collection service in 1995 (Ogu, 2000) and irregular collection has been recorded in Maiduguri by Dauda and Osita (2003).

Management = 25

5.6.2.3 Responsibility Issues Indicator – Information Dissemination ($J_{3.1}$)

The responsibility issues indicator has been allocated a score of 50. This is attributed to the almost non-existent information circulation with respect to the informal sector in addition to its limitation of accessibility to the literate amongst the adult population. This is because interpersonal communication, posters, TV and radio programs are scarcely available while the latter has been identified to most effective means of transmitting information (Issa and Sunday, n.d.). Other deterrents to information circulation include lack of standard procedure for information acquisition and scarcity of funds to publish information materials (Akintola *et al*., 2009). Meanwhile, the formal sector working with waste seems to have an effective means of information distribution via workshops, training programs and conferences (Akintola, *et al*., 2009).

Responsibility issues = 50

5.6.2.4 Technologies Indicator – Breakdown of conveyance Fleet ($J_{4.1}$)

This technologies indicator scored 50 points because the non-fuel based vehicles tend to be in frequent operation whereas the fuel based vehicles break down frequently (FME, 2004). While the formal sector depends on the fuel based vehicles such as trucks to transport waste, the informal sector rely on the non-fuel based vehicles such as wheel barrows (Wilson *et al*., 2009) that are suitable for areas with narrow and unpaved roads prevalent in the peri-urban areas of Kaduna metropolis. The non-fuel based vehicles are manufactured locally and can therefore be operated and maintained locally. No record of long downtime of these vehicles has been found in existing literature.

The frequent breakdown of the fuel based vehicles point out the necessity for waste managers and policy makers to focus beyond importing apparently successful strategies without further research while involving the informal sector as suggested by Nabegu (2010). In situations where foreign imported strategies are in place, more intensive personnel training is a viable option as suggested by Imam *et al*. (2008).

Technologies = 50

5.6.3 The Social Indicators

High scores were generally attained by the social indicators. The highest score of 100 points was attained in this category by the social equity indicator, intra and inter generational equity.

Table 5.3.3 Social indicators

Economic Indicator	Description	Final score
Health - $K_{1,1}$	Contact with waste	**50**
Quality of service – $K_{2,1}$	Stakeholders' satisfaction	**70**
Stakeholder involvement – $K_{3,1}$	Awareness	**64**
Social equity – $K_{4,1}$	Intra-generational and inter-generational equity	**100**

5.6.3.1 Health – Exposure to Waste ($K_{1.1}$)

The health indicator was assigned a score of 50. This is attributed to the waste dumps within communities found across the city with fourteen infamous sites identified by the Kaduna environmental protection authority (KEPA) in 2008 (Hussaini, 2008). The communal dumpsites are generally piled up with waste collected at irregular intervals of over two weeks (Dauda and Osita, 2003; Abdullahi *et al*., 2008). Meanwhile, direct contact by households is minimized due to the frequent evacuation of waste to the nearest communal site carried out by the informal sector and householders (Afon, 2007). The final disposal facilities are generally situated on the outskirts of the city where no residents are found. A visit to two major disposal facilities for Kaduna metropolis showed no residents within a great distance of the sites.

Health = 50

5.6.3.2 Quality of Service – Stakeholders' satisfaction ($K_{2,1}$)

The quality of service indicator attained a score of 70. The solid management scheme evaluated involved both formal and informal sector provision of service. Despite the informal sector characterized by improper disposal and health issues, residents indicated a high level of satisfaction with their services with a score of 69.8/100 because collections are carried out at the convenience of residents (Afon, 2007; Nwaka, 2005). In addition, cost is negotiated to the satisfaction of parties involved (the residents and waste collector(s) (Afon, 2007).

Quality of service = 70

5.6.3.3 Stakeholders' Involvement – Awareness ($K_{3,1}$)

The stakeholders' involvement indicator, awareness, scored 64 obtained directly from the study of Babayemi and Dauda (2009). Despite high awareness level recorded, the streets in Kaduna are generally littered with waste. The lack of improvement in the environment, although awareness is high may be due, partly, to lack of infrastructure (Ayotamuno and Gobo, 2004; Ifegbesan, 2010).

Stakeholders' involvement = 64

5.6.3.4 Social Equity Indicator – inter and intra generational equity ($K_{4,1}$)

The score for this indicator was accorded 100 points because communal waste site were found to be situated across all socio-economic groups and the final disposal sites were located at the outskirts of the city. A visit to two major dumpsites in Kaduna with Kaduna environmental protection agency (KEPA) staff showed no residents within 500m radius to the sites. In addition, communal dumpsites are available within all districts regardless of the socio-economic status of the residents living in the districts. However, inequity exists due to the waste collection services depending on the ability of households to pay the private sector in addition to other criteria such as willingness to pay and concern over disposal habits of the informal sector (Afon, 2007). Furthermore, the predominant waste disposal and treatment methods of open dumping and burning (Walling *et al*., 2004) mitigates the negative effects of encapsulated waste by allowing most of the organic waste to decompose in a relatively short time.

Social equity = 100

5.6.4 The Economic Indicators

The two economic indictors scored the same points of 50. This is similar to the weightings assigned to the economic factors by solid waste management practitioners, where both employment and total cost were accorded the same weights.

Table 5.3.3 Economic indicators

Economic Indicator	Description	Final score
Employment - $L_{1,1}$	Job creation	**50**
Total cost – $L_{2,1}$	Service cost quantification	**50**

5.6.4.1 Employment indicator – Job creation ($L_{1,1}$)

The indicator for job creation scored 50 for Kaduna metropolis as a result of employment created by and for the informal sector with wages greater than the minimum wage in Nigeria. This is because the formal sector employs fewer strategies that involve collection and disposal while the informal sector engages in resource recovery in addition to collection and disposal (Osita and Dauda, 2003; Kofoworola, 2007; Wilson *et al*., 2009). Meanwhile, the informal sector working in the waste sector has good wages compared to the state minimum wages and provides a means of livelihood especially with their low level of formal education, obtaining a score of 100/100 for the second indicator (Nzeadibe., 2009). Meanwhile recycling, reuse and composting are practiced, incineration and landfilling especially with energy recovery are non-existent. Monthly income of waste pickers from four urban cities were found to be $153, $48.3, $99.3 and $84.9 in relation to minimum wage $75, $35, $35 and $35 showing informal sector income to be higher than the state minimum wages (Agunwamba, 2003). In recent studies, the lowest earning informal sector group reported an average monthly income of $154 compared to the state minimum wage of $55.6 where one dollar equals ₦117 was used in the study (Nzeadibe and Ajaero, 2010).

Employment = 50

5.6.4.2 Quantification of service cost – Public versus Private Sector ($L_{2.1}$)

The total cost indicator was assigned a score of 50 as a result of the cost of waste management allocated by the authorities not adequate to support an effective management strategy. However, there is existence of private sector participation. The waste management authorities have allocated ₦78,000,000 per month to manage in Kaduna (Hussaini, 2008), which amounts to approximately ₦103 per person per month. Meanwhile, the private sector charges approximately ₦2000 per month per household (Ibrahim, 2010), which translates to approximately ₦364 per person per month considering 5.5 persons per household (Adeoti *et al*., 2001). There is a general under-costing of funds required by the government agencies from subsidies allocated inherent in Nigeria (Ogwueleka, 2009). This may be attributed to scarce resources that put a cap on the funds available to carryout basic services in addition to lack of personnel capacity within the agencies and departments (Adedibu, 1988; Imam *et al*., 2008). Furthermore, revenue from material and energy recovery is scarce as there are no formal recovery facilities in the Kaduna city similar to many Nigeria cities (Wilson *et al*., 2009).

Total cost = 50

5.6.5 Application to index

The scores of the indicators outlined in figures 5.3.1 to 5.3.4 are applied to the SI function (Equation 1) to derive the index for Kaduna metropolis.

$$SI = 0.0650I_{1i} + 0.103I_{2i} + 0.103I_{3i} + 0.070J_{1i} + 0.073J_{2i} + 0.073J_{3i} + 0.064J_{4i} + 0.078K_{1i} + 0.053K_{2i} + 0.062K_{3i} + 0.037K_{4i} + 0.110L_{1i} + 0.110L_{1i}$$

$$SI = 0.0650I_{1,1} + 0.103I_{2,1} + 0.103I_{3,1} + 0.070J_{1,1} + 0.073J_{2,1} + 0.073J_{3,1} + 0.064J_{4,1} + 0.078K_{1,1} + 0.053K_{2,1} + 0.062K_{3,1} + 0.037K_{4,1} + 0.110L_{1,1} + 0.110L_{1,1}$$

SI = 0.065(0) + 0.103(0) + 0.103(0.5) + 0.07(0.80) + 0.073(0.25) + 0.073(0.5) + 0.064(0.5) + 0.078(0.5) + 0.053(0.7) + 0.062(0.64) + 0.037(1) + 0.11(0.5) + 0.11(0.5) = **0.457**

The scores presented in table 5.3 were applied to the sustainability index function to obtain an index of **0.457**.

5.7 CONCLUSION

The environmental indicators scored the least points amongst the four aspects of solid waste sustainability assessment. The air and water quality had exceptionally low scores due to the uncontrolled sites that are located all over the city, which are used as communal collection sites. The management strategy indicates the presence of leachate in surface and groundwater and a high level of smoke in the air. The highest score in the environmental category, attained resources conservation, is as a result of the recycling and reuse driven by the informal sector.

The economic indictors attained equal scores that are higher than the environmental indicators. These scores are likely due to informal sector that make an adequate living, in terms of wages, from waste collection and recycling services they provide. Highest scores were attained by the social indicators. The lowest score in the category, scored by health, is generally attributed to the frequent contact of residents to decomposing waste. High level of residents' satisfaction with the services provided by the informal sector was also reported in addition to a high level of awareness despite many areas characterised by waste dumps. The highest score was recorded for the social equity indicator as a result of the same waste services provided across all socio-economic groups. Furthermore, the main methods of disposal (open burning and open dumping) indicate waste decomposes at a faster rate and hence reduces or eliminates the transfer of negative impacts to future generations. The scores

attained by the administrative indicators follow were generally low with a notably high score attained by the policy indicator due to established waste management departments in the two environmental agencies in Kaduna. In addition, regulations established have been established in the region although a few key issues have not been addressed in the regulations.

The index for Kaduna metropolis was found to be **0.457**. While comparison with other strategies will give more meaning to the index, the lower the index, the less effective and efficient the solid waste management strategy in place. Of greater significance is that the assessment has shown that the model developed in the previous chapters can be used to evaluate solid waste management schemes. However, the need for reliable data is demonstrated especially in developing countries such as Nigeria.

5.8 SUMMARY

Sustainability assessment of the solid waste management strategy in Kaduna metropolis was carried out to illustrate the performance of the strategy in place. Kaduna metropolis, the former administrative headquarters of the northern region in Nigeria, is one of the most prominent political, industrial and economic centres in Nigeria. With a population of 1,563,300, it has been identified among the major cities where integrated waste management facilities will be constructed. The investigation encompassed household and commercial solid waste disposed generated within Kaduna metropolis for the duration of a year. This includes emissions and materials flowing within the system and between the system and the environment. The basic waste management process of temporary storage, collection, transportation, treatment and disposal was employed during analysis.

One indicators was identified for each factor (making up a total of thirteen indicators) to ensure the list remains manageable. The environmental indicators had the lowest scores compared to the economic social and administrative indicators mainly due to the uncontrolled emission of leachate and particulate matter into the environment from the huge number of waste dumps across the city. Generally higher scores were established for the social indicators. The low scores in that category allocated to awareness and participation was because of inadequate facilities and proper communicated schedules that hinder the participation of stakeholders in waste management activities despite a report of high awareness level. The administrative indicators have relatively low scores but a high score for the policy indicator. The two economic indicators scored equal points of 50. This is attributed to jobs created by the informal sector with adequate wages compared to the state minimum wage in the case of the employment creation indicator. Meanwhile, the evidence of full cost analysis by the local authorities appears lacking while it seems necessary for the private sector to achieve the cost

analysis as profit making organisations. The scores attained by the indicators are applied to the SI to obtain an index of **0.457**. The assessment has shown that the model developed in the previous chapters can be used to evaluate solid waste management schemes though the need for consistent baseline data has been established.

Chapter six brings together the results obtained in Sections four and five in a general discussion. It includes a reflection of the methodology adopted and the general participant response.

6.0 SUSTAINABLE SOLID WASTE MANAGEMENT

6.1 INTRODUCTION

The discussion in this section will be focused on assessing solid waste management schemes. The results obtained from the attempt at quantifying sustainable development with regards solid waste management using a questionnaire survey is also addressed. The study has attempted to incorporate the social, economic, environmental and administrative aspects and their factors to ensure a comprehensive appraisal method is established. Most studies in the area of sustainability of solid waste management imply or explicitly adopt the equality of the evaluative aspects (Bosshard, 2000; McDougall and White, 2001; Imran *et al*., 2008; den Boer *et al*., 2007), while the aspects have been shown to have varying significances in this study.

The chapter also includes the differences in importance recorded across the various sectors and regions although an overall function was determined. The structured questionnaire survey adopted in conjunction with analytic hierarchy process was found to be appropriate for generating the weightings of the various elements used in developing the assessment tool. The response of the waste management practitioners to the survey and its delivery mode are also discussed. This is in addition to willingness of waste management practitioners to take part in the survey, mode of questionnaire delivery and effects of gender and ethnicity of the researcher.

In addition, the case study analysis of the waste management strategy in Kaduna metropolis will also be addressed with particular attention to source of data and identification, scoring and normalisation of indicators. Furthermore, the applicability of the assessment tool with regards to other situations or regions will be examined.

6.2 SOLID WASTE MANAGEMENT ASSESSMENT TOOL

An attempt at quantifying sustainable development with regards solid waste management provides an approach for consistent and uniform appraisal of strategies. From the survey, the multi-faceted nature of solid waste management seems to be perceived by the practitioners based on the consensus on suitability of SD to build an assessment tool. Administrative and social issues were raised alongside economic and environment concerns during the survey. The solutions to waste management issues traditionally have been based on technical principles, while many assessment methodologies are based on economic and environmental models (Morrissey and Browne, 2004; Onwurah *et al*., 2006). The technical dimension

highlighted in the traditional solution to management of solid waste is generally addressed in the administrative aspect within this study. The technical solutions usually take environmental and economic elements into account. The emphasis on environmental dimension is evident in the present dominance of LCA application (that developed rapidly during the 1990's) for assessment of solid waste management schemes (Finnveden, 1999; Clift *et al*., 2000). In addition, this study has attempted to incorporate the social, economic and administrative aspects and their factors to ensure a comprehensive appraisal compared to the main focus on environmental impact categories of the LCA studies (Moberg *et al*., 2005). However, a similar pattern to certain LCA procedures (scope definition and inventory analysis) was employed to assess a case study in Nigeria in Section five and in the course of building the assessment tool (Finndeven *et al*., 2005). These processes included the category selection of aspects, classification of the factors under the aspects, weighting of the aspects and factors and indicator selection and scoring (Moberg *et al*., 2005).

Quantifying sustainable development to build an assessment tool in this study has resulted in establishing an equation based on the four evaluative aspects and thirteen factors following the themes of these aspects. The process involved obtaining subjective but experienced opinions of knowledgeable stakeholders within the solid waste industry in deriving weightings for the aspects and factors. However, the weightings are close in significance, between 22% assigned to the economic aspect and 27% assigned to the administrative aspect. The environmental aspect was recorded a close second in significance and social aspect the third. However, economic aspect rated the least important remains crucial due to funding and affordability considered as major constraints and challenges of solid waste management in Nigeria (Imam *et al*., 2008).

6.2.1 Differences across regions

Although an overall function was determined, the significance assigned by the various sectors and regions have differences. Significances assigned across sectors are generally in agreement with little differences in values. Meanwhile there is significant statistical difference across the regions with the biggest differences recorded in the environmental and administrative factors category. The differences are greater amongst the factors compared to the aspects. High weightings accorded to any specific aspect or factor is usually associated with heightened awareness of stakeholders of an issue that is unique and prevalent in that particular sector or region.

6.3 THE SURVEY AND APPLICATION OF AHP

The structured questionnaire survey adopted in conjunction with AHP was found to be appropriate for generating the weightings of the various aspects and factors that were used in developing the assessment tool. As discussed in Section 2.3.6, AHP is amongst several MCDA models used in identifying stakeholder priorities found to be suitable for dealing with complex systems that involves several alternatives such as solid waste management (Soma, 2003; Bottero and Peila, 2005). The application of AHP for measuring the sustainability assessment aspects and factors effectively considered the relevant parameters, including those that are difficult to measure and/or require subjective measure as the primary means of appraisal. AHP has been applied successfully 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). The applicability of AHP to quantify sustainable development with respect to solid waste management is presented below.

- It takes into account the diverse stakeholders within the industry with often conflicting opinions and arrives at a consensus while checking, measuring and minimizing inconsistencies (Garfi *et al*., 2009; Bello-Dambatta *et al*., 2009)
- It is associated with an ease of use due to its hierarchical feature that enables natural structuring of decision problems (Ramanathan, 2001; Saaty, 2008)
- It simplifies and concentrates reality into a comprehensive framework that can be used for assessment including situations with scarce data that is invaluable to Nigeria (Soma, 2003)
- Finally, the software used for its analysis is user-friendly and accessible (Leung *et al*., 1998; Soma 2003)

While review of literature was conducted to identify list of evaluative factors and aspects for AHP comparison similar to Garfi *et al*., 2009, many reports indicate the stakeholders' engagement in generating the list such as research carried out by Contreras *et al*., and Arnette *et al*. (2008; 2010). Engaging the stakeholders requires more time and resources and may result in losing some participants between the time of establishing contact and administering the questionnaire particularly the informal sector that usually lack established addresses.

Generally, AHP is applied using questionnaires either in workshops as shown by Lai *et al*. (2002), Brent *et al*. (2007), Garfi *et al*. (2009), Arnette at al. (2010) or individual administration as in the case of Bottero and Peila (2005), Contreras *et al*. (2008) Sambasivan and Fei, (2008).

Most research in Nigeria qualitatively evaluate and describe the status of solid waste management strategies of various states (Dauda and Osita, 2003; Imam *et al*., 2008; Abdullahi *et al*., 2009; Adewole, 2009; Babayemi and Dauda, 2009). Many studies suggest the elements to be measured within the strategy but fail to specify technique(s) of measurement, scoring and /or normalisation (Sergio, 1993; Klundert and Anschutz, 2001). Quantitative studies establishing the status of management strategies include those established for the ASEAN countries developed by UNEP (2005); by Lang *et al*. (2007) that adopted many methods in achieving systemic SD assessment but dealt with specific aspect of solid waste management – landfilling. Strategic environmental assessment is an approach that uses indicators but focuses on ensuring environmental issues are considered at the planning stage on par with economic and social considerations (Salhofer *et al*., 2007).

6.3.1 Participation of waste management practitioners

The practitioners were generally found to be willing to participate in the survey across all the sectors and regions. A few cases of reluctance to respond to the questionnaires were recorded in Maiduguri within the state government and private sectors that resulted in a low participation rate for the private sector category, the lowest recorded across all regions. Meanwhile, the unwillingness of the state government sector was overcome by careful discussion and a high number of questionnaires were eventually administered, the highest recorded for that sector across the five regions. The educational qualifications of the two sectors (state government and private sector) were found to be generally low especially the formal and informal private sector within Maiduguri in particular. However, the informal private sector in Kaduna and Lagos in particular were found to be keen on taking part in the survey.

6.3.2 Questionnaire delivery

The questionnaire delivery uniformly adopted across the five regions and four sectors was, in one instance, deviated from during the field studies based on the recommendation of the participants. The questionnaire was administered to a group of six state government sector participants in Maiduguri at once and resulted in very similar responses. Although open discussions are encouraged for participants to have transparency and greater insight into the subject matter (Brent *et al*., 2007), it appeared some of the lower ranking participants had adopted the choices of their superiors. Additional pictures generated to aid the questionnaire administration for the informal sector in particular were not required to enhance understanding and were therefore discarded.

6.3.3 Effects of gender and ethnicity of researcher

The questionnaire administration was achieved quicker in the Southern parts of the country away from the base and origin of the researcher. Next day and later-in- the-day appointments were granted at short notices in Lagos (south-west), Maiduguri (north-east) and especially Port Harcourt (south-west). In many instances, questionnaires were administered once introductions and distance of researcher from base was established. Although there was general willingness to participate in the survey, it was difficult to obtain appointments in Lagos. Despite an alliance with an indigene of the region for the questionnaire administration, it had the lowest participation rate. However, the university strike reduced the number of academic participants available for the survey.

With regards to gender, there has been no evidence in existing literature of negative attitude of respondents towards researchers on the basis gender.

6.4 APPLICATION OF SUSTAINABILITY ASSESSMENT TOOL – CASE STUDY

The solid waste management strategy in Kaduna metropolis was appraised to derive an index of **0.457.** Generally, high scores assigned to indicators will result in a high index, which suggests an effective strategy. Meanwhile, high coefficients within the sustainability function indicate areas of high priority.

6.4.1 Data source

The attempt to test the sustainability assessment tool in Section Five illustrated the scarcity of baseline data for solid waste in many regions of Nigeria. For instance, the data for solid waste composition in Kaduna is limited to the studies of Olaniyan *et al*. and Anake *et al*. (2009; 2009) and that of effectiveness to Nwude *et al*. (2010). Meanwhile, data on cost and organisational structure of the waste authorities is hardly available. Wilson *et al*. reported the inadequacy of the data on the informal sector participation in Nigeria that is more acute in the Northern regions (2009) as evidenced in Maiduguri where the private sector were hard to reach. Although correspondence has improved with improved internet and phone access in Nigeria, tracking certain groups was difficult due to their informal type operations (Afon, 2007).

In addition to the data scarcity, the reliability of data depends on collection methodology, researcher capacity and/or journal of publication (which indicates the robustness of peer review of a study). For instance the study carried out by Wilson *et al*. (2009) on the informal sector is reported in an international journal while the work of Nwude *et al*. (2010) is a Masters dissertation and therefore scarcely reviewed.

6.4.2 The indicators

A further break-down to arrive at measurable quantities is achieved by subdividing the factors into indicators (Klang et al., 2003). At that point, scores are assigned to the indicators and applied to the derived function to obtain an index. The indicators, selected to assess a case study in Chapter Five, attempted to illustrate a clear relationship to sustainable development and solid waste while taking into account national and global priorities shown in the hierarchy in Section 4.3 and Table 5.2 as recommended by Bohringeer and Jochem (2007). Indicators selected generally had specific or representative data available in existing literature.

Although the function is universal within the context of its development, the assessment tool is designed to involve stakeholders and/or researcher(s) (i.e. participatory) in identifying the indicators, scoring and normalisation procedures for each investigation.

6.4.3 Scoring and normalisation of indicators

An indicator specified for each factor was normalized and aggregated to achieve the index of **0.457** for Kaduna metropolis. Methods of scoring and normalisation for the identified indicators were generally adopted from various studies previously identified. The techniques (i.e. methods of scoring and normalising) were predominantly adopted from the report of UNEP (2005) for assessing solid waste management strategies of ASEAN countries; Lang *et al*. (2007), Sergio (1993) and Desmond, (2006). Similar scoring and normalisation methods were employed for all the indicators for which the methods were not directly found within available literature hence the use of indirect methods in some instances.

6.5 APPLICABILITY OF THE SUSTAINALITY ASSESSMENT TOOL

The tool developed is recommended for regions or situations that are similar to Nigeria in terms of stakeholders and/or existing distinct difference between management and regulations, where enforcement usually features as a major issue that suggests weak institutional capacity such as Ghana, Jordan, Philippines and China (Boadi and Kuitunen, 2003; Qdais, 2007; Wilson *et al*., 2009). During the course of piloting the survey, some participants in the UK indicated the two factors of management and policy as intertwined and without distinct divide. However, in countries with inherent inadequate policies; enforcement issues and ambiguity in roles, responsibilities and relationships (Agunwamba, 1998; Ayotamuno and Gobo, 2004; USEPA, 2010), it suggests regulations are not strictly adhered to and are therefore not synonymous with management. While stakeholders considered in building the tool include the waste generators, the informal and formal waste managers and the federal state and local

authorities the waste generators were not directly involved in the assessment tool development due to limited time and resources.

Generally, there is a distinct difference in the environmental quality and management schemes of regions where informal sector participation is evident globally. The presence of informal waste managers, mainly in developing nations (Wilson *et al*., 2006; Afon, 2007), is normally associated with unplanned and inadequate formal collection and disposal; unorganised recycling; heaps of uncollected waste in public spaces; inadequate funding and high poverty level (Dauda and Osita 2003; Ayotamuno and Gobo, 2004). Meanwhile the issues of solid waste management in developed countries tend towards reduction of waste quantity and recycling ensuring minimum damage to public health and environment (Salhofer *et al*., 2007; Chandak, 2010).

6.6 SUMMARY

An attempt at quantifying sustainable development with regards solid waste management resulted in the development of an assessment tool based on four principles of SD. The procedure involved obtaining experienced opinions of waste management practitioners in creating an assessment function that was used to establish the status of the strategy in Kaduna metropolis of Nigeria. The research also established the significances of the four aspects to be similar but unequal contrary to what is generally accepted.

The structured questionnaire survey adopted in conjunction with AHP was found to be appropriate for generating the weightings of the various aspects and factors that was used in developing the assessment tool. Practitioners were generally found to be willing to participate in the survey across all the sectors and regions with a few cases of reluctance encountered in two regions – Lagos and Maiduguri. The questionnaire was delivered uniformly across all regions and sectors by one-on-one questionnaire administration with the exception of some state government sector participants. There was general interest to participate in the survey by all ethnicities across the country except for a bit of reticence in Lagos. The quick response and cooperation of the participants and individuals associated with the field work suggests sympathy to the cause of a female researcher.

Finally, the tool developed is recommended for regions or situations that are similar to Nigeria in terms of stakeholders and/or existing distinct difference between management and regulations.

7.0 CONCLUSION, RECOMMENDATIONS AND FUTURE WORKS

7.1 CONCLUSION

Steady increase in waste variety and quantity coupled with highly inefficient and ineffective solid waste management system in Nigeria evidenced by waste dumps in drains and public spaces has established the need for improvement (Ayotamuno and Gobo, 2004; Imam *et al*., 2008). Despite environmental agencies set up by the various states in Nigeria, the deterioration of the urban environment remains a challenge to the communities especially the local government that are constitutionally responsible for managing the waste (Adedibu, 1986; Afon, 2007). The system is based on temporary storage within households and/or communal dumpsites; collection and transportation to final disposal sites for open burning and open dumping and a small but significant recycling of 8-22% by the informal sector (Imam et al., 2008; Wilson *et al*., 2009).

To improve existing strategy, a comprehensive assessment approach is essential to establish the performance of present strategy, to provide information to stakeholders and a platform for discourse (Anschutz, 2004). Most methodologies adopted for assessing the strategies are based on three model - cost benefit analysis (CBA), life cycle assessment (LCA) and multi-criteria analysis (MCA) (Morrissey and Browne, 2004). Meanwhile, application of sustainable development has gained prominence in the recent past, where sustainable waste management emphasizes a shift from waste disposal to other waste management options that includes energy and material recovery as well as waste reduction and reuse in addition to the aim of decoupling increase in waste generation from economic growth, a natural progression in many nations (Chung and Lo, 2003; EEA, 2005; Desmond, 2006). It includes a strategy in place that is appropriate to the local conditions and has a balance between technical, environmental, social, economic, financial, administrative and political aspects, and is capable of maintaining itself over time without exhausting the resources it needs (van de Klundert, 2000; Joseph, 2006). It also has to take into account the multiple dimensions of the system and various stakeholders with often conflicting opinions.

While the generic principles of sustainable development consist of social, environmental and economic aspects, the administrative aspect has been evaluated in many studies involving waste management (van de Klundert, 1996; van de Klundert and Anschutz 2000; Chung and Lo, 2002; Hayward and Gaskin 2005; Desmond 2006), it is especially relevant in developing countries with emerging economies and legislature and ambiguity in the regulations (Ayotamuno and Gobo, 2004).

The study is an attempt to develop a solid waste management assessment tool for Nigeria and similar countries in response to the demand for reliable, coordinated and understandable information.

7.1 METHODOLOGY

The methodology adopted involved using a structured questionnaire survey in conjunction with AHP. Review of literature identified sustainable development as a suitable concept to use in building an assessment tool. The assessment tool was developed by establishing the evaluative aspects based on the principles of sustainable development that include the three traditional environmental, social and economic aspects and the addition of the administrative aspect that has gained prominence in the recent past (van de Klundert, 2000; McDougall and White, 2001; Chung and Lo, 2003; Joseph, 2006).

The structured face-to-face questionnaire survey was administered by researcher after an initial pilot survey using postal questionnaire survey. The change was necessitated by request of participants for further clarification on the scale of measurement and topic content as well as the need for personal delivery and retrieval of questionnaires to participants specific to Nigeria. The function is designed to be used in illustrating the sustainability of specified solid waste management schemes. AHP was adopted as the data collection instrument to obtain the weights from waste management practitioners.

AHP has been applied successfully 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 are carried out using AHP as a tool (Brent *et al*., 2007; Contreras *et al*., 2008; Garfi *et al*., 2009; Chun-hsu Lin *et al.,* 2010). Its extensive use in environmental management illustrated its suitability for use in resolving differences of opinion among various stakeholders in the selection of preferred option(s) in waste management.

The eighty-seven practitioners surveyed represent the work sectors and diverse regions in Nigeria. The general function was established using statistical analysis while individual weightings were determined with the application of AHP. The analysed survey data established general significance of the aspects and factors as well as the significances specific to the five regions and four sectors. Kruskal Wallis statistical analysis was employed to find differences in weightings assigned by practitioners across sectors and locations.

7.2 RESULTS AND DISCUSSION OF QUESTIONNAIRE AND LITERATURE SURVEY

General support has been established for application of SD as a concept to develop a solid waste management assessment tool as well as its breakdown in a three level hierarchy. A common function (Equation 1) was derived from the data analysis of the data generated by the questionnaire survey based on the hierarchy in Section 4.3 involving the evaluative aspects as the main themes.

Equation 1

$$\begin{aligned} \mathrm{SI} = {} & 0.065\mathbf{I_{1i}} + 0.103\mathbf{I_{2i}} + 0.103\mathbf{I_{3i}} + 0.07\mathbf{J_{1i}} + 0.073\mathbf{J_{2i}} + 0.073\mathbf{J_{3i}} \\ & + 0.064\mathbf{J_{4i}} + 0.078\mathbf{K_{1i}} + 0.053\mathbf{K_{2i}} + 0.062\mathbf{K_{3i}} + 0.037\mathbf{K_{4i}} \\ & + 0.11\mathbf{L_{1i}} + 0.11\mathbf{L_{2i}} \end{aligned}$$

The four aspects of sustainability (environmental, administrative, social and economic) were found to have different weightings within a close range of 22-28% with administrative aspect as the most significant despite its absence as a generic principle of sustainable development in the past. A need for regrouping some of the factors under the main themes indicated by a few respondents reflects the variation of chosen grouped criteria across different studies. This study has established that though close in importance, some aspects and factors have greater priority over others.

Although a common function is determined, the work sectors and regions have differences in the significance accorded to the various aspects and factors. There is general agreement across sectors on coefficients while significant statistical differences exist between regions on some coefficients namely the factors of environmental and administrative aspects. Generally wider variations between weightings were distinguished across regions compared to sectors for the factors and aspects even where statistical significant differences were not recorded. High weightings assigned by regions or sectors generally reflect heightened awareness and problem areas for that region or sector. For instance, the private and state government sector have assigned high weightings to management and responsibility issues due to their responsibility of managing and handling waste directly. These aspects are subdivided into factors for which indicators are to be specified, scored and aggregated to provide the index.

7.3 CASE STUDY- KADUNA CITY

The solid waste management strategy in Kaduna metropolis was assessed and an index of **0.457** was established. As the third most populous state after Lagos and Kano with a population of 1,563,300, it has been identified among the major cities where integrated waste

management facilities will be established. The case study analysis encompassed household and commercial solid waste disposed and generated within Kaduna metropolis for the duration of a year. This includes emissions and materials flowing within the system and between the system and the environment. The basic waste management process of temporary storage, collection, transportation, treatment and disposal was employed during analysis.

The function established in Section four (Equation 1) was used to analyse the existing strategy and to create an index for Kaduna metropolis. An indicator was identified for each factor (making up a total of thirteen indicators) to ensure the list remains manageable. The environmental indicators scored the least points amongst the four aspects of solid waste sustainability assessment. The air and water quality had exceptionally low scores due to the uncontrolled sites that are located all over the city, which are used as communal collection sites. The management strategy indicates the presence of leachate in surface and groundwater and a high level of smoke in the air. The highest score in the environmental category, attained resources conservation, is as a result of the recycling and reuse driven by the informal sector.

The economic indictors attained equal scores that are higher than the environmental indicators. These scores are likely due to informal sector that make an adequate living, in terms of wages, from waste collection and recycling services they provide. Highest scores were attained by the social indicators. The lowest score in the category, scored by health, is generally attributed to the frequent contact of residents to decomposing waste. High level of residents' satisfaction with the services provided by the informal sector was also reported in addition to a high level of awareness despite many areas characterised by waste dumps. The highest score was recorded for the social equity indicator as a result of the same waste services provided across all socio-economic groups. Furthermore, the main methods of disposal (open burning and open dumping) indicate waste decomposes at a faster rate and hence reduces or eliminates the transfer of negative impacts to future generations. The scores attained by the administrative indicators follow were generally low with a notably high score attained by the policy indicator due to established waste management departments in the two environmental agencies in Kaduna. In addition, regulations established have been established in the region although a few key issues have not been addressed in the regulations.

The index for Kaduna metropolis was found to be **0.457**. While comparison with other strategies will give more meaning to the index, the lower the index, the less effective and efficient the solid waste management strategy in place. Of greater significance is that the assessment has shown that the model developed in the previous chapters can be used to evaluate solid waste management schemes. However, the need for reliable data is demonstrated especially in developing countries such as Nigeria.

7.4 GENERAL DISCUSSION

An attempt at quantifying sustainable development with regards solid waste management resulted in the development of an assessment tool based on four principles of SD. The procedure involved obtaining experienced opinions of waste management practitioners in creating an assessment function that was used to establish the status of the strategy in Kaduna metropolis of Nigeria. The research also established the significances of the four aspects to be similar but unequal contrary to what is generally accepted.

The structured questionnaire survey adopted in conjunction with analytic hierarchy process was found to be appropriate for generating the weightings of the various aspects and factors that was used in developing the assessment tool. Practitioners were generally found to be willing to participate in the survey across all the sectors and regions with a few cases of reluctance encountered in two regions – Lagos and Maiduguri. The questionnaire was delivered uniformly across all regions and sectors by one-on-one questionnaire administration with the exception of some state government sector participants. There was general keenness to participate in the survey by all ethnicities across the country except for a bit of reticence in Lagos.

Finally, the tool developed is recommended for regions or situations that are similar to Nigeria in terms of stakeholders and/or existing distinct difference between management and regulations. Applied to the case study in Section six, the index of **0.457** suggests a moderate strategy considering an absolute value system of measurement. However, comparison with other assessed strategies, which are presently unavailable, will be a more effective means of establishing the state of the scheme. Generally, high scores assigned to indicators will result in a high index, which suggests a better strategy.

The result illustrates complexity of SD assessment and the regional difference highlighted indicates context as highly influential. However, the common function derived was applied to generate an index illustrating the applicability of the assessment tool.

7.5 FUTURE WORKS

7.5.1 Application of the sustainability assessment tool

The solid waste management strategy in Kaduna metropolis has been evaluated and an index of **0.457** established. For a more effective and critical evaluation, the appraisal of other strategies is essential to make comparisons.

The case study assessment carried out in this study (Section 5) was specific to household and commercial waste. The evaluation of other waste sources such as agricultural, demolition and construction and industrial waste can be performed with the assessment tool.

Furthermore, observation-based indicators were employed in the waste management scheme assessment of Kaduna metropolis with data obtained from existing literature, mainly journal articles and conference papers. Assessments can be improved by using consistent baseline data and measurement-based indicators in conjunction with the local authorities and other stakeholders.

7.5.2 Re-administrating the survey

Lagos represents the south-west and fresh water swamp zone of Nigeria. The biggest differences recorded in the results of the weightings were obtained from this location and Maiduguri. Due to some unique features of Lagos city, re-administering the questionnaire survey will further validate or refute the result from the south-west zone. It will also take high forest zone into consideration, which covers the largest area in the southern part of the country (Ogunsote and Ogunsote, 2002).

As the old capital of the Nation, the solid waste management problem in Lagos is mainly aggravated by its high population density, the highest in the country at 100 per sqm. It was characterised among the dirtiest cities in the world prior to the present administration since 2007 when the waste authorities became notably active and more effective. Lagos has been recorded as the most prominent commercial and industrial centre in Nigeria and hence the large population. As a coastal region within the fresh water swamp zone, it is susceptible to flooding due to blocked drains from solid waste.

Because regional differences have been found in the study, re-administrating the survey in another country is recommended.

7.5.3 Baseline data

The need for baseline data has been established by this study. Consistent collection of data by the waste management authorities is therefore recommended. Furthermore, there is the need for constant and continuous research on solid waste trends and management in institutions. In addition, the private sector must be encouraged to keep proper records that can be used as data sources.

7.6 SUMMARY

This chapter has presented the conclusions of the thesis. It includes background information, problems, aims and objectives of the study as an attempt to provide a means of assessing solid waste management schemes with the view to make improvements, especially in countries where general health and well-being of inhabitants is threatened by solid waste. A waste management assessment tool has been developed and tested where context has been found to be influential in the case of the assessment tool due to regional differences recorded in the study. The study further highlights the need for consistent baseline data as the core for carrying out assessments as shown in the cause of testing the tool by assessing a waste management scheme in a Nigerian city, Kaduna.

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"Sustainable Development (SD) as defined by the United Nations Conference on Environment and Development (UNCED) in 1992 suggests a development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

'Brunner et al., describes the aims of Sustainable Waste Management in line with SD as protection of human health and environment, and conservation of resources in a manner that does not impair the wellbeing of current and future generations.'

The issue of measuring sustainable development arises in order to assess waste management systems sustainably. Four evaluative s aspects are derived to carry out the assessment – Environmental, Economical, social and institutional aspects.

Aspects

Environmental aspect - rational resource consumption that can be achieved by conservation of the resources during and by the waste management process and reduction of environmental pollution, which protects the environment and health (Chung and Lo, 2003; den Boer et al., 2007; Hung et al., 2007; Roussat et al., 2007).

Institutional aspect - The administrative aspect encompasses policy, which provide guidelines for management; management that decides the running of every aspect of the system within the policy framework; research and training that provide knowledge on further management options to take; and responsibility issues, which determine the roles of all stakeholders and technologies used to provide waste management services (van de Klundert and Lardinois, 1995; Walmsley *et al*., 2001)

Social aspect - ensure human health and well-being in this generation and future generations; involving society in waste management processes and promoting members of the society to work together in achieving short and long term goals of waste management (Imam et al., 2008).

Economical aspect - takes into account total cost for waste management which includes pollution prevention cost, social cost and etc in the short and long run (Imam et al., 2008).

1. Do you think the concept of Sustainable development is an appropriate concept to use in the assessment of systems?

Yes ☐	No ☐

2. Is it suitable to be used in assessing waste management?

Yes ☐	No ☐

3. Is it practicable to breakdown sustainable development into the aspects above to analyse the waste management system?

Yes ☐	No ☐

This is the proposed model of the aspects broken down into criteria and indicators (measurable units) illustrated in Fig 1.

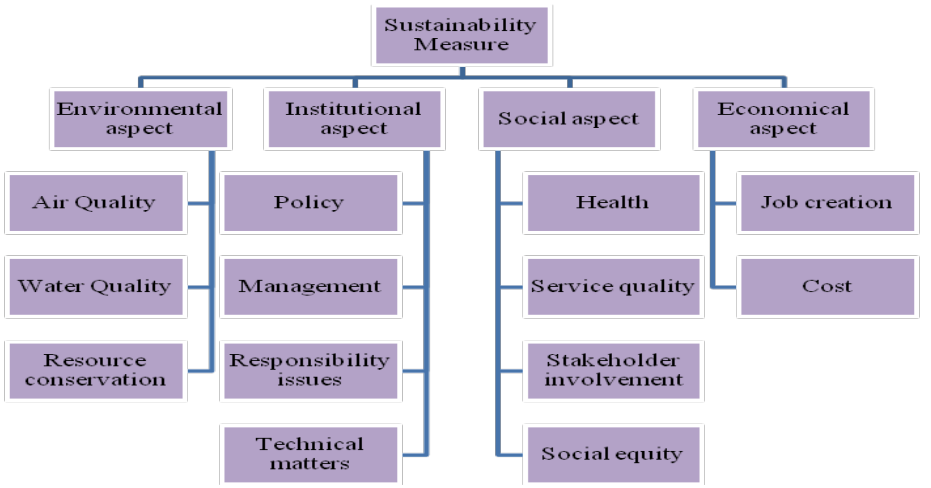

Fig 1. Sustainable Waste Management hierarchical structure

Please compare importance of the aspects then the criteria in the hierarchical structure using a pair wise comparison scale. The elements placed at the two extreme ends of the scale have the most significance; equal importance at the center point and the importance of each element over the other reducing as it moves towards the center. Select a point on the scale that signifies the importance between two elements in each scale. The aspects are represented in Questions four to nine and criteria; questions ten to twenty-five.

The pair wise comparison

Environmental aspect				Q4				Institutional aspect
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Environmental aspect				Q5				social aspect
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Environmental aspect				Q6				Economical aspect
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Institutional aspect				Q7				social aspect
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Institutional aspect				Q8				Economical aspect
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Social aspect				Q9				Economical aspect
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Criteria for Environmental aspects

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

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

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

Criteria for Institutional aspects

Policy				Q13				Management
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Policy				Q14				Responsibility issues
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Policy				Q 15				Technical matters
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Management				Q16				Responsibility issues
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Management				Q17				Technical matters
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Responsibility issues				Q18				Technical matters
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Criteria for Social aspects

Health				Q19				Service quality
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Health				Q20				Stakeholder involvement
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Health				Q 21				Social equity
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Service quality				Q22				Stakeholder involvement
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Service quality				Q23				social equity
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Stakeholder involvement				Q24				Social equity
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Criteria for Economical aspects

Job creation				Q25				Cost
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Policy issues

What method do you think will improve waste management practices and drive it up the waste management hierarchy?

Rewards/Incentives				Q26				Punishment
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Public sector service provision				Q27				Private sector participation
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Informal sector

Despite the Informal sector characterised by unregulated and unregistered provision of service with high health and safety risks, the recycling option of the waste management is well developed in developing nations due to their input as well as providing a much needed source of livelihood. Select most beneficial arrangement with respect to sustainable development of waste management strategy where the informal sector plays a role.

Informal sector inclusion				Q28				Formal sector service provision
9	7	5	3	1	3	5	7	9
Significantly more important				Equal				Significantly more important

Respondent details

Sector: Central government ☐ Local government ☐

Academic sector ☐ Private sector ☐

Other _____

Qualification: MSc ☐ BSc ☐ PhD ☐

Other _____

Discipline Waste management ☐ Environmental science ☐

Civil/environmental Engineering ☐ Geology ☐

Other _____

Experience: 2 – 5 yrs ☐ 6 – 10 yrs ☐ > 10yrs ☐

Other _____

Sex: Male ☐ Female ☐

Please add any comments or suggestion:

_____

_____

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_____

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_____

Please check that you have answered all questions.

Addressed and stamped envelope for questionnaire return has been provided.

Return to:

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University of Portsmouth | Department of Civil Engineering

Agency and Respondent details

Organization/agency..... Completed by.....
..... Position.....
Department & Region..... E-mail.....

Background

1. Rate the appropriateness of applying sustainable development to assess waste management

1	2	3	4	5
Totally inappropriate	Hardly appropriate	Moderately appropriate	Very appropriate	Extremely appropriate

2. Do the four aspects in figure 1 (first level) suitably represent the goals of sustainable waste management?

Yes ○ No ○

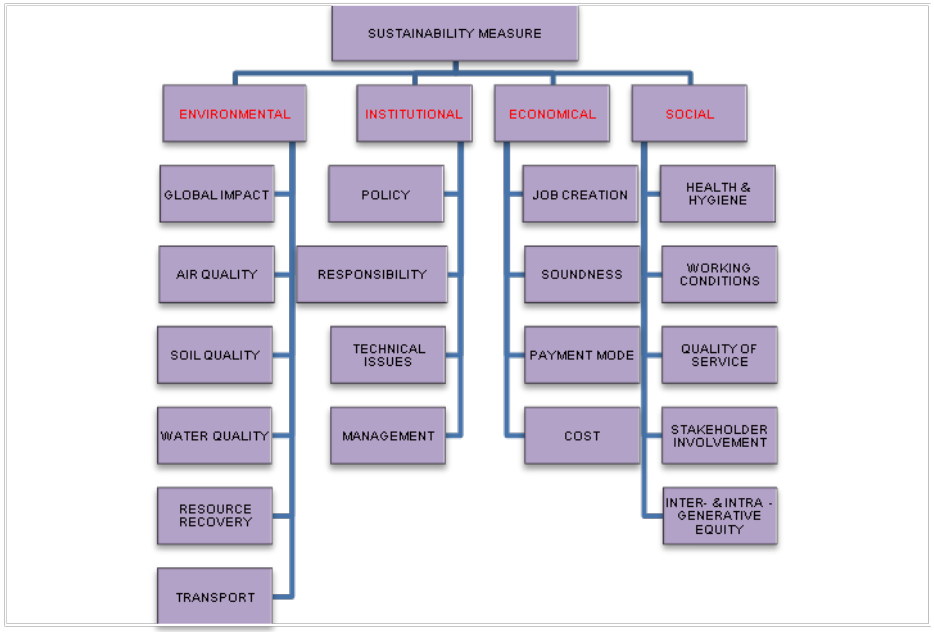

Fig 1. Hierarchical structure of sustainability assessment aspects, criteria & indicators

3. Are the four aspects of sustainability of equal importance?

Yes ○ No ○

If yes, go to question 4.

4. Rank the list of sustainability aspects in order of importance using the ranking key below and rate the aspects to sum up to 100%.

Table 2: Ranking key

1	2	3	4	5
Weakly important	Less important	Moderately important	More important	Extremely important

ASPECTS	RANKING	RATING
Environmental	[ ]	[ ]
Institutional	[ ]	[ ]
Economical	[ ]	[ ]
Social	[ ]	[ ]
Total		100

Environmental aspects

5. Rank and rate criteria relevant to environmental aspects according to format in question 3 above.

Table 3. Rankings & ratings of criteria relevant to environmental aspects

Criteria	Indicator	Ranking	Rating
Global impact	Green house gas emissions - CO_2 & CH_4		
Air quality	SO_x, NO_x, CO_2, CH_4 and dioxins		
Soil quality	Heavy metals		
Water quality	COD, BOD, NH_4, pH, Heavy metals, Suspended Solids, volatile suspended solids, Volatile fatty acids		
Transport	CO_2 emission		
Resource conservation	Quantity & quality of energy & material from waste Following waste management hierarchy – various options and their percentages		
Total			100

6. Are the indicators of the criteria appropriate?

Yes ○ No ○

7. Are the criteria exhaustive? Please refer to tables 1-4

Yes ○ No ○

8. Are the criteria overlapping one another?

Yes ○ No ○

Comments & suggestions.....
.....
.....
.....

Institutional aspects

9. Rank and rate the criteria relevant to institutional aspects according to format 1.

Table 3. Rankings & ratings of criteria relevant to institutional aspects

Criteria	Indicator	Ranking	Rating
policy	Compliance and adequacy of waste management policies		
Responsibility issues	Awareness of Stakeholder roles and carrying out the duties		
technical	Adapted to the physical environment, topography & other physical requirements; distances to users; Locally manufactured; use on indigenous technology; Optimum equipments use; Repair & maintenance ability; local spare parts availability; Long life expectancy		
Management	Ease of operation; Skill level of employees; Research and training (capacity building) & creating room for involvement of stakeholders		
Total			100

10. Are the indicators of the criteria appropriate?

Yes ○ No ○

11. Are the criteria exhaustive?

Yes ○ No ○

12. Are the criteria overlapping one another?

Yes ○ No ○

Comments & suggestions.....
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Economic aspects

13. Rank and rate the criteria relevant to economical aspects according to format in 3.

Table 4. Rankings & ratings of criteria relevant to economical aspects

Criteria	Indicator	Ranking	Rating
Employment creation	No. of jobs		
Soundness	Expenditure Vs income of service providers (based on full cost analysis and recovery)		
Mode of payment	Establish mode in use; satisfaction of users		
Cost	Operational & capital cost Capital		
Total			100

14. Are the indicators of the criteria appropriate?

Yes ○ No ○

15. Are the criteria exhaustive? (Please refer to Figure 1)

Yes ○ No ○

16. Are the criteria overlapping one another?

Yes ○ No ○

Comments & suggestions.....
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Social aspects

Rank and rate the criteria relevant to social aspects according to format in 3.

17. Table 5. Rankings & ratings of criteria relevant to social aspects

Criteria	Indicator	Ranking	Rating
Health & hygiene	Effect of noise; accidents, injury, illnesses; fire hazards; impact on amenity and landscape		
Employment	Working conditions		
Quality of service	Convenience; reliability,& effectiveness; affordability; complaints system & resilience		
Stakeholder involvement-	Awareness - Waste management options; consequences of actions; global & local threat; participation- waste diversion & acceptance of strategy in place		
Intra- and inter-generative equity	Nearness of facilities to any specific income, social, ethnic or religious group; Uniformity of service across all groups Necessity for monitoring after operational life & Duration of monitoring after operational life		
Total			100

18. Are the indicators of the criteria appropriate?

Yes ○ No ○

19. Are the criteria exhaustive?

Yes ○ No ○

20. Are the criteria overlapping one another?

Yes ○ No ○

Comments & suggestions.....
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Conclusion

Please add any further comments about sustainable waste management systems:

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Please check that you have answered all questions

Thank you very much for your help by completing this question

Please (√) if you would like a copy of the result summary ○

Contact Details

Please return this completed questionnaire in the stamped envelope provided, to:

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KADUNA STATE GOVERNMENT
REGULATION NO. 1 OF 2009
SOLID WASTE MANAGEMENT
KADUNA STATE ENVIRONMENTAL PROTECTION AUTHORITY
SOLID WASTE MANAGEMENT REGULATION NO. 1 OF 2009
Commencement: 1st January, 2009

In exercise of the powers conferred upon the Authority by Section 5(2) of Kaduna State Environmental Protection Edict No. 1 of 1994, and of all other powers enabling me on that behalf, I Mal. Ibrahim Garba Hussaini hereby make the following Regulations: -

1. (i) It shall be the duty of every owner or occupier of any premises (public or private) to clear and keep free from all overgrowth, weeds, filth, rubbish and refuse of any description, the street at the front, back, both sides and inside the premises.

(ii)It shall be the duty of the owner of any premises to provide drainage system at the front, back and both sides of the premises together with gutters and channels in and around the premises.

(iii)The owner or occupier of any premises shall clean and maintain the drainage system in the premises in such a manner as to prevent or avoid blockage of the drains.

(iv)Where there are two or more premises contagious to any street, drain, gutter or channel and facing each other, the owners or occupiers of each premise shall be responsible for keeping clean, half of the street and the drain, gutter or channel nearest to their premise.
2. No person shall: -

(i)Throw, lay or deposit on any street, gutter, open space, drain, or on any premises, whether occupier or not, any litter, refuse, waste matter of whatever description or any unwholesome matter, except at such places as may be authorized by the Authority.
(ii) Abandon; dump, or deposit any refuse upon the public highways or other public property except in a sanitary landfill site approved by the Authority.

(iii) Abandon any vehicle in any public place or facility that will be a nuisance to the public or an impediment to transportation.

3. (i) Every owner or occupier of premises shall provide and maintain refuse receptacle, made of galvanized iron or plastics, of not less than 20 inches in diameter, 3 feet high, and having an effective capacity of not less than 5 cubic feet, with a tight fitting cover; for the purpose of storing refuse prior to removal by authorized person(s) or to an authorized collection site.

(ii) Every driver of commercial vehicle operating in any part of the State shall provide, make use and maintain a waste bin in his vehicle at all times.

(iii)The size, number and the location of the refuse receptacle in any premise shall be determined by the Authority or authorized person(s).

(iv)Every owner or occupier of any premises shall remove daily or allow authorized persons to remove at regular interval, refuse from the receptacle, to an authorized place.

4. It shall be the duty of each Local Government Authority in the State to: -

(i) Locate, construct, and maintain public refuse receptacles in strategic places, where residents in its area may deposit their household waste.

(ii)Collect the waste from such public refuse receptacles in strategic places, where residents in its area may deposit their household waste.

(iii)Permanently station at least one labourer to maintain and tidy each public refuse receptacle in its area.

5. (i) No person shall establish or operate any household waste collection business without first obtaining a license to be issued by the Authority.
(ii) A Local Government Authority which proposes to enter into any contract for the collection of household waste shall comply with the following requirements before making the contract, and if it does not, any contract made by it shall be null and void: -
(a)The Local Authority shall publish in at least two publications circulated among the waste collection contractors, a notice containing a brief description of the contract work.
(b)A statement in the notice that any person who wish to submit a tender for the contract must notify the Local Authority of his wish within a specified period of time.

(c)If any persons notify the Local Authority, in accordance with the notice, of their wish to submit tender for the contract, the Local Authority shall invite each person to tender for the contract.

(d)The Local Authority shall award the contract to the firm that fulfils the following requirements: -

(i)Must be registered under Company's and Allied Matters Decree of 1990.

(ii)Must be registered with Kaduna State Environmental Protection Authority as a refuse contractor.

(iii)A Local Authority which enters into any contractual agreement with any person shall notify the State Environmental Protection Authority, within one month from the date the contract was awarded, with the following information.

(a)The name of the persons the contract was awarded.
(b)A brief description of the contract work.
(c)The date the contract will terminate.

6. All private waste contractors should ensure they renew their licenses on yearly basis. Any officer of the Authority may be authorized to enter at all reasonable hours, the office of any private waste contractor for the purpose of inspecting his license or refuse collection equipment.

7. It shall be the duty of any person or body corporate, while transporting waste of whatever description, sand or gravel to cover the vehicle in such a way that the waste, sand or gravel do not escape from the transporting vehicle or plant, thereof litter the highway or any street.

8. (i) It shall be the duty of each Local Authority as respects any highway and major roads, to ensure that the land and the street are kept clean of liter, refuse or overgrowth of grasses and weeds.

(ii) While discharging its duties under subsection (1) above, the Local Authority shall place and maintain on such highways or major roads, traffic signs and barriers as may be necessary for preventing danger to traffic or for regulating it, and afterwards to remove them as soon as they cease to be necessary for those purposes.

(iii) The Local Authority, while discharging its duties in subsection (1) and (2) above shall at the same time comply with any directives given to it by the highway or road authorities.

9. It shall be the duty of the Authority to: -

(i) Arrange for the collection and disposal of commercial and industrial solid waste in the State.
(ii). Arrange for places at which industries or facilities may deposit their solid waste prior to collection by authorized persons to any authorized landfill site.

(iii) Specify the design, size and number of refuse receptacle each industry or facility shall provide and where to locate such receptacle in their premise.

(iv) Enter into any contractual agreement with any persons for the collection and disposal of commercial and industrial solid waste in the State.

10. It shall be the duty of the Authority to: -

(a) Acquire waste with a view to its being recycled.
(b). Make arrangement with licensed waste contractors for them to use waste for the purpose of producing from it heat, or electricity or both.

(c) Make arrangement with licensed waste contractors for them to recycle waste.

(d) Use, sell, or otherwise dispose of waste as respects anything produced from such recycled waste.

11. (i) No person, body corporate or Local Authority shall operate and maintain a landfill site without a permit issued by the Authority.

(ii) The minimum requirement to be considered by the Authority before issuing a landfill permit shall include: -
(a) The landfill /dump site shall be located entirely above the season high water table.

(b) The landfill/ dump site shall be underlain with an impermeable layer which is designed and constructed in such a manner as to prevent the migration of liquid in and out of the landfill/ dump site.
(c) A leachate detection, collection and removal system should be constructed and operated to remove accumulated liquid from the system as quickly as possible.

(iii) The Authority shall specify in the permit any other requirement and operating practices that are necessary in the day to day operation of the landfill/dump sites.

(iv) The Authority may operate and maintain its landfill/dump sites and give directives to Local Authority or licensed refuse contractors where such landfill/dump sites are located, to transport and where to dispose their solid waste to these landfill/dump sites owned by the Authority.

(v) The Authority may charge fees for every Kilogramme of solid waste to be disposed off in landfill/dump sites owned by the Authority.

12. No person except an authorized person shall disturb, sort over or remove: -
(a) Any private refuse receptacle.
(b) Anything deposited in a private or public waste receptacle.
(c) Anything deposited in a landfill/dump site.

13. All reasonable costs and expenses incurred in carrying an order into effect may be recovered by the authority from the person by whose act, default or sufferance the offence was committed, and in the case offence caused by the act or default of the owner of premises, such cost and expenses may be recovered from any person who is for the time being owner of such premises.

14. (i) It shall be the duty of every Local Authority in the State to
appoint officers that shall enforce the relevant sections of these Regulation in their respective Local Authorities.

(ii) In situations where any Local Authority in the State did not enforce any section of these Regulations, the State Environmental Protection Authority shall be responsible for enforcing any section of these Regulations.

15. Any person who willfully hinders, prevents or obstruct any authorized officer or other person in the execution of these Regulations shall upon conviction be liable to a fine of twenty thousand Naira (N20,000.00) only or to an imprisonment of not more than three months or both.

16. Any person, Authority, Corporate body or unincorporated including Government Agencies or their representatives who fail to comply with any of the provisions of these Regulations shall be guilty of and on conviction, in the case of an individual to a fine of not more than One Hundred Thousand Naira (N100,000.00) or not more than five years imprisonment and in the case of a firm, corporation or authority to a fine of not less than One Hundred Thousand Naira (N100,000.00 and not more than One Million Naira (N1m).

17. These Regulations may be cited as Kaduna State Environmental Protection Authority, Solid Waste Management Regulations No. 1 of 2009.

MADE at Kaduna this 1st day of January, 2009

Mallam Ibrahim Garba Hussaini
General Manager
Kaduna State Environmental Protection Authority