IMPROVING WASTE LOGISTICS IN KUMASI METROPOLITAN AREA

BY

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DECLARATION

I, IBRAHIM HAMDU, author of this thesis, do hereby declare that, this submission is my own work towards my Master of Science degree in Agro-Environmental Engineering and that, to the best of my knowledge; it contains no materials previously published by another author nor materials which have been accepted for the award of other degree of the university, except references to other people's work which has been duly acknowledge in the text.

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DEDICATION

This work is dedicated to all my family and friends, especially my parents Mr. Ibrahim Sumani, Hajia Fati Iddrisu, my sisters, my children Iyin and Hakim, my dear one Hamdu Wasila and the entire family whose patience, prayers and encouragements made this dream a success.

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ABSTRACT

In the light of recent discussions about cost and environmental effectiveness of waste management structures, the cost involved in the management of municipal solid waste in Kumasi at present is vey huge due to uncontrolled urbanization. Large quantities of waste are generated daily in Kumasi, and this exerts much pressure on an-over strained solid waste management system. Therefore waste logistics models are needed to

describe the influences and complex interactions within the entire waste management chain. This study looked at waste collection and disposal systems using four different models in the city of Kumasi.

The study was conducted on the four waste collection models using structured questionnaires and personal interviews. In all, a total of 180 households were randomly sampled and interviewed in the Kumasi metropolis to understand how waste is collected, transported and disposed off. Another set of questionnaires were administered to interview all the stakeholders that were involved in the collection, transportation and disposal of waste in the metropolis. Each model was identified by city authorities and each of these models was traced in two sub metropolis. The geographical locations of all the collection points, transportation routes and the disposal points were identified using the global positioning system (GPS) to develop the logistics map of Kumasi. The results of the collection points were plotted in the digital map of Kumasi using GIS to develop the waste logistics map of Kumasi. The results of the study showed that, only households registered under the house to house collection system were provided with collection materials but the residents did not like the collection system because its mode of waste collection was not frequent. The households under the KNUST waste collection system were very satisfied with the collection system because the collection was done every day. The results also revealed that, all the waste collected by waste collection companies are transported to the landfill for disposal. The only recyclables picked by rag pickers at the landfills are plastics and metals. The rag pickers collect these materials and sell them to middlemen who then transport these materials to Tema for processing. The study also revealed that Kumasi metropolis had no recycling centre and nutrient and energy recovery centre where these waste can be utilized.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the study

Solid waste management is a growing environmental and financial problem in countries throughout the world (Hari *et al*, 1994). Despite significant efforts made by some countries in recent decades to improve solid waste management services, most municipalities and metropolitan cites in developing countries still face major challenges in properly handling the growing volume of waste produced in their cities (Majani, 2000; Kaseva and Mbuligwe, 2003; Kitbuah *et al.*, 2009). Increasing population, economic activities, urbanization and industrialization especially in developing countries such as those in Africa, have drastically increased the amount of waste generated (Taylor, 1999)

Waste collection systems vary widely between different countries and regions. In Ghana, waste collection services are often provided by local government authorities or by private waste management companies (Kitbuah *et al.*, 2009). The two collection methods practised in Ghana are the communal and the franchised methods. The communal method of waste collection has several waste collection points called transfer stations located in the communities where all the waste are gathered from households and from other public institutions before they are transported to the disposal sites. In the franchise method of waste collection, the waste is collected from homes, institutions and in public places and transported to the disposal sites. The communal collection is used in areas where the residential houses are not well planned and there are no good road networks to ensure house to house collection.

1.1.2 Definition of waste logistics

The concept of waste logistics has not been widely used within the waste management studies. However, the term *Reverse logistics* is used rather frequently to refer partly to waste. In this study, the term waste logistics will be used throughout the text. Logistics is the flow of material, information and money between consumers and suppliers or disposal such as in case of waste. (Thomas, 2005). It incorporates the planning and execution of activities to move products from their origin to destination (Frazella, 2002). Logistics is defined as the management, control of the flow, storage of materials, information, financial services between suppliers and consumers (Bowersox, 2002). It includes all the activities undertaken to move the product from its origin to its destination. In this regard, waste logistics can be understood as all the activities undertaken to move waste from its source of generation to the final disposal point (Roel *et al.*, 2010).

1.2 Problem statement

Municipal solid waste management in Kumasi is at present delivered in an unsustainable manner. Due to uncontrolled urbanization, large quantities of waste are generated daily in Kumasi, and this exerts much pressure on an-over strained solid waste management system. Coupled with weak institutional capacity, and lack of resources, both human and capital, the city authorities face difficulties in ensuring that all the waste generated in the city is collected for disposal. This provides complex multidimensional negative effects for human health risk and environmental contamination.

Developed countries have well developed facilities for collecting waste and the logistic systems are developed to ensure smooth flow of material from one point to another where as in developing countries there is lack of and or inadequate waste collecting

facilities and organized management to ensure a smooth flow of the waste from one point to another (Tettenborn *et al*., 2007).

Comprehensive studies have been made on waste management in most developed and developing countries. However, little attention or research has been made on logistics aspects and therefore there is a great knowledge gap in this field of study hence the need for this study.

For developed countries, this is not a particularly difficult task since there are existing data from long-term characterization studies and monitoring of the solid waste streams both on the local and national level. However, such data for developing countries with economies in transition are virtually nonexistent. The solid waste stream in these countries could exhibit dramatic changes as a result of increased economic growth; changes in social, ethnic, religious or cultural structure, opening of markets, or influx of new products and ideas (Lakshumi *et al*., 2006).

The technological advancement in packaging of commodities especially food items such as candies, ice creams, fast food joints, vegetables and fruits using wrappers, bottles, papers, tins and polythene bags to increase their market value is expected to double the amount of waste generation in the next decade (Isaac and Ernest, 2004). For instance the black polythene bag that is commonly used by all shops, roadside sellers and vendors in packaging every item that is sold in the markets and along the streets of Ghana can be seen hanging on fences, in gutters and drains. These polythene bags block drains.

However there are no hard and soft infrastructures most especially in Africa to handle this increasing amount of waste that is generated. Environmental sanitation plants and equipment are very expensive and not easily accessible because they are mostly imported thus making procurement of the equipment and its supplies a major operational issue. The human resource and the technical expertise are lacking as well

as the institutions and organizations responsible to handle and manage the waste. Above all, there are no effective waste logistics systems in place and they are yet to be developed to ensure smooth flow of waste from collection points to the disposal sites.

1.3 Research Questions

During the 1980s, the International Monetary Fund/World Bank led a structural adjustment programme which sought to privatize state owned institutions involved in the collection, transportation and disposal of solid waste in Ghana especially in Accra and Kumasi to allow for greater participation of the private sector (Isaac and Ernest, 2004). The introduction of the private sector in the waste collection service has greatly improved sanitation in Kumasi due to the quantities of waste collected in the city. The private companies remove a minimum of 1,000 tonnes of garbage every day from their allotted zones within the city (Republic of Ghana, 1991). However there are still media reports criticising the Kumasi Metropolitan Assembly (KMA) of its inability to collect waste within the city. Some residences are rejecting the house to house collection because their waste is not regularly emptied and this poses health problems to their families. The question that still remains unanswered is why is the waste management department not able to collect all the waste generated within the city? To help answer this question, the following sub questions would be useful:

1. Has the waste management department developed the waste collection systems to address the current waste management problems?

2. Has the waste management department ensured that adequate waste logistics are provided at all levels of waste collection streams to ensure effective waste collection?

1.4 Objective of the study

1.4.1 Main objective

The main objective of the study was to develop an effective waste logistics system in the Kumasi Metropolitan area to improve the environment and public health.

1.4.2 Specific Objectives

- To map out the different models of waste collection, transportation and disposal in the municipality.
- To recommend an effective waste logistics system for the Kumasi metropolitan area.

1.5 Justification of the study

The first step in developing an effective solid waste logistic system is to establish legislation, regulations and proper managerial practices that are specific enough to address the characteristic needs of solid waste systems in the Kumasi area. In 2006, the Kumasi metropolitan area was generating 1000 tonnes of waste a day and only 600 tonnes were collected (Ghana Statistical Service, 2006) and as at June 2009, the Kumasi metropolitan area was generating 1500 tonnes of waste per day and out of this amount only 1000 tones was collected (KMA, 2009). KMA spends about 30-50% of its annual budget in waste collection and disposal (KMA, 2006) and these funds could be used for other development projects

Mapping out the existing waste logistic flows in the city will reveal all the inefficiencies in the collection stream thus identifying new areas of research that can have the greatest impact in shaping the waste management systems in the municipality. It will also ensure effective waste logistic planning which will enhance innovative ways of collection to

reduce the environmental impact, public health risk and the cost of collecting and disposing of waste

The findings of the proposed study is therefore to provide a deeper understanding of the distribution pattern for waste generation from all the corners of the city and the collection chains from one point to another. This would be done by tracing the collection routes in each sub metro within the metropolis. This is essential prerequisite for planning and implementing logistical frame work that aims to provide sustainable and efficient waste collection system within the Kumasi city.

This will also provide adequate data for researchers, development officers, policy makers, organizations and institutions that intend to make interventions to develop both the soft and the hard infrastructure of the waste collection system in this area to improve the environment and public health.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter reviews the relevant literature obtained from the studies to provide the context within which this study can be properly understood. The topics covered in this chapter include solid waste generation**,** waste collection methods, vehicles used for waste collections, waste processing, waste conversion and waste disposals

2.2 Solid waste generation

Solid waste is defined as all waste arising from human and animal activities (Tchobanogblous *et al,* 1993). This encompasses all the heterogeneous as well as all the homogenous mass of waste materials from community accumulations of agricultural, industrial and mineral wastes. Waste generation is described as the quantity

of materials or products that enter a waste stream before composting, incineration, recycling and land filling (Business Directory.com, 2009). Waste generation includes all the activities in which materials that are no longer of value and are either thrown away or gathered together for disposal. Solid wastes are generated from residential areas, commercial or public places, industries, treatment plants and agricultural activities. According to (Kerala ENVIS Centre, 2009), solid waste generation is mainly due to industrial and domestic activities. The centre added that solid waste generated from industrial activities is of hazardous as well as nonhazardous nature, while solid waste generations from domestic sources are mostly organic.

2.3 Waste Generation Quantities

According to the European Union municipal waste generation report of 2008, Municipal waste quantities in Europe is growing and more than 306 million tonnes are estimated to be collected each year with an average of 415 kg/capita. About 18 million tonnes of waste is generated in Greater London each year which covers an area of 1,587 square kilometres (Browne and Allen, 2007). In Ghana, about 3 million tonnes of solid waste is generated annually with an average of 0.45 kg per capita. Accra, the capital city and Kumasi the second largest city, combine to generate about
3,000 tonnes of solid waste daily (Mensa and Larbi, 2005). According to the Mayor of Kumasi Metropolitan Assembly, the city of Kumasi in 2009 generates an average of 1,500 tonnes of solid waste daily with an estimated population of about 2 million people. Out of this amount the KMA is only able to collect about 1,300 tonnes leaving the remaining 200 tonnes uncollected due to inadequate waste collection logistics (KMA, 2009).The manufacturing industry, construction and demolition, mining, quarrying and agriculture are the main sectors that contribute to waste generation in Kumasi (Sarpong, 2009).

Determining the total amount of waste generated is very important information when selecting the right kind of logistics in waste collection and transport. This will guide the selection of specific equipment for collecting the waste, designing waste collection routes, material recovery facilities and disposal facilities (Tchobanogblous *et al*, 1993).

2.4 Source and types of solid wastes

The sources of solid waste are residential, commercial, municipal, industrial, open spaces, treatment plants and agricultural. Table1 indicates the different sources of solid waste and the types of waste that are generated from these sources. The various types of solid waste that are generated include food waste, rubbish, ashes and demolishing and constructional waste. Solid waste can be classified into different types depending on their sources:

1. Household waste generally classified as municipal waste,
2. Industrial waste as hazardous waste, and
3. Biomedical waste or hospital waste as infectious waste

In Ghana solid waste refers mainly to:

- Domestic waste (waste from food preparation, sweeping, discarded household items),
- Municipal waste (waste generated in commercial centres),
- Industrial waste (e.g. wood waste, waste from abattoirs and food processing industries, metal scraps from garages). (Poku, 2009).

The knowledge of the sources and the type of waste generated coupled with the amount of waste generated is a very important information required for the design of logistics

facilities for effective handling and management of the waste to protect the environment and public (Tchobanogblous *et al*, 1993).

Table 1: Typical solid waste generating facilities, activities and locations associated with various sources of classifications.

Sources	Typical facility location where waste is generated	Types of waste
Residential	Single family and multiple family Low, medium and high apartments dwellings	Food waste and rubbish ashes.
Commercial	Stores, restaurants, markets, office buildings, hotels, motels, print shops, auto repair shops, medical facilities and institutions etc	Food waste, rubbish, ashes, demolishing and construction, occasional hazardous waste
Municipal	As above	As above
Industrial	Construction, fabrication, light and heavy manufacturing, refineries, mining and power plant demolishing	Food waste, rubbish, ashes, demolishing, construction, occasional and hazardous waste
Open areas	Street alleys, parks, vacant lots, play grounds, beaches, highways recreational areas	Rubbish
Treatment plants sites	Water, waste water and industrial treatment processes	Treatment plant wastes, agricultural wastes and hazardous wastes
Agricultural	Farms, feedlots, field and row crops	Agricultural wastes

Source: Tchobanogblous *et al*, 1993.

2.5 Waste collection

The term waste collection includes not only the collection of solid waste from various sources but also the hauling of these wastes to the location where the contents of the collection vehicles are emptied (Tchobanoglous *et al*., 1993).

Waste collection is also described as a component of waste management which results in the passage of waste materials from the source of production to either the point of treatment or final disposal site **(**Sampson, 2003).

The way and manner in which waste is collected in terms of vehicle types, capacities, staffing levels and round configuration depends on the nature of the collection. For example household / commercial, and the contractual arrangements put in place (working hours, disposal points, materials collected and receptacles used, e.g. black bag, wheelie-bin, orange sack). According to Tchobanogblous *et al*, (1993), waste collection starts with the containers holding materials that a generator has designated as no longer useful and ends with the transportation of the solid waste to a location for processing or disposal.

In high income areas, the private waste collection companies collect the waste directly from households with compactor trucks for dumping whiles in low and middle income areas, residents carry their waste to public waste containers provided by the Waste Management Department at communal collection points (Boadi and Kuitunen, 2003).

2.5.1 Household and commercial waste collection

Household wastes are generally generated from homes. They are gathered in waste bins, plastic or metal containers, plastic bags for collection by waste collector using a waste collection vehicle. The waste generated from households are carried to central waste collection point (transfer stations) where they would be loaded into a vehicle and either sent to a landfill site or to an alternative waste treatment facility. The amount of waste generated from households and commercial places far exceeds the volume collected. According to Boadi and Kuitunen (2003), 60% of the total waste generated in Accra is collected annually leaving the 40% uncollected. According to the Kumasi Waste Management Department (2009), and the private waste management companies in

Kumasi, their inability to collect all the waste generated from the households and the commercial areas are as a result of poor road network within the city, inadequate waste collection containers and the frequent break down of bulldozers and compactors at the landfill site. According to Boadi and Kuitunen, (2003), households resort to alternative ways of disposing their waste. For instance in high income areas waste bins are not emptied in time forcing residence to hire individuals to dispose of the waste at the central collection points. In low income areas, the containers are not removed in time and this causes people to dump waste in unauthorized dumps such as canals, water bodies, and surface drains.

2.6 Logistics of solid waste collection

Past methods of planning for and operating waste collection systems are under pressure, resulting from the need to improve the collection systems to protect the environment and public safety. Sampson, (2003) stated in his report that waste collection and transport has significant environmental, health and safety implications as well as the economic cost due to the types of logistics that are used to collect and transport the waste. The total quantity of waste generation keeps increasing coupled with the nature and type of waste produced in our technological society gives the complexity of the type of logistics requires for the collection of waste.

There are a number of barriers that limit efforts to improve the efficiency of waste collection logistics **(S**ampson, 2003). These are:

- The inconsistent nature of waste production, with variations occurring on a weekly and seasonal basis and from street-to-street and region-to-region,
- Access restrictions, meaning that not all properties can be serviced by the same vehicles,

- Ineffective matching of vehicles to rounds, and
- Variations in material delivery points over time, a situation that will arise more frequently as material reprocessing and delivery to new markets increases.

To improve the efficiency of waste collection logistics the following may be considered:

- Raising the issue of logistics earlier in the planning phases of integrated waste management systems,
- Phased introduction of new collection schemes such that transport problems can be addressed and costs more fully understood prior to full scheme adoption,
- Partnership working, e.g. through shared depots,
- Improved understanding of the capabilities of the asset-base,
- Collection and use of operational performance data to inform future planning,
- Effective periodic work scheduling and routing, and
- Contingency planning, e.g. for unplanned closure of waste disposal facilities.

2.6.1 Composition of solid waste

Information on the composition of solid waste is important in evaluating alternative equipment needs, systems, and management programme and plans for solid waste collection (Tchobanoglous *et al*., 1993). For instance, if wastes are generated from a commercial facility that consists of only paper products, the use of special processing equipment such as shredders and balers may be appropriate. Separate collection may also be considered if different city collection agencies are involved. According to (Mizpah *et al*., 2009), the composition of solid waste in the Kumasi city is predominantly made of biodegradable materials and high percentage of inert materials

which include wood ash, sand and charcoal. Table 2 shows the solid waste composition in the Kumasi area.

Table 2: Waste composition data in Kumasi

Waste component	Percentage
Biodegradable or organic	64
Paper	3
Plastic	4
Metals	1
Glass	-
Others	-
Inert	22
Wood	3
Textiles	3

Source: Mizpah *et al.,* 2009

2.6.2 Waste collection materials

Waste containers are used for storing waste and they are usually made of metal or plastics. Common terms used for waste containers are dustbins, rubbish bins, litter bins, garbage cans, bin trash and rubbish barrel. These bins are classified according to their usage as indoor bins, curbside bins and public bins for public areas. Indoor bins are traditionally kept in the kitchen to dispose of food waste but in recent times they are also used in the offices to dispose of papers and other office waste. The top of these bins are sealed to trap the odour inside the bin that the garbage tends to emit. Though most of them have to be opened manually, some have pedals, which open the lid when stepped on. Indoor bins are also lined with garbage bags which keep the bin clean, facilitate the removal of the garbage and allows disposal with minimal contact with the contents. Curbside bins consist of three types, which include the trash cans, dumpsters and wheel bins. All of these are placed at the gate of the residence to dispose of their waste and emptied by waste collectors. In areas where there is recycling or

energy/nutrient recovery service, separate bins are placed at residences to receive items that can be recycled or used as biogas or compost. Bins in public areas such as parks are placed alongside paths frequently walked by people to encourage them to dispose of their waste inside them to avoid littering the environment.

2.6.3 Waste collection service/ methods

Solid waste collection systems and methods in Kumasi are inadequate to cover a large part of the city, particularly, in poor squatter settlements, and inaccessible neighborhood to collect all the expected waste to be generated in the cities (Boadi and Kuitunen, 2003). The principal types of waste collection methods are collecting comingle or non-separated waste at source and waste at source separated. Waste collection methods vary widely between different countries and regions. Domestic waste collection services are often provided by local government authorities, or by private industry. Developing countries do not have a formal waste-collection system even though these countries are now adopting some of the popular waste collection systems around the world. For instance in Australia, the curbside collection is the method of disposal of waste where every urban domestic household is provided with three bins: one for recyclables, another for general waste and another for garden materials. These bins are provided by the municipality if requested. In Ghana the Metropolitan, Municipal and District Assemblies are responsible for the collection and final disposal of solid waste through their Waste Management Departments (WMDs) and their Environmental Health and Sanitation Departments

(www.ghanadistrics.com, 2009). Accessed on the 18th August, 2009.

There are two main types of waste collection services that are delivered by the private operators in the Kumasi metropolitan area. These are house-to-house and communal collection services. The patronage of the house-to-house collection services increased

from 2.1 per cent of the population in 1999 to 20.8 per cent as at March, 2005 after Peter *et al*, (2009). as shown in Table 3 below. It was observed that residents of the city are willing to patronize the service if satisfactory levels of service could be guaranteed.

Table 3: Estimation of house-to-house coverage in Kumasi

Year	Projected population	Number of houses served	Number of persons served	Percentage %
1991	1,112,423	900	23,130	2.1
2000	1,170,270	2,200	56,540	4.8
2001	1,231,124	4,300	64,810	6.9
2002	1,295,143	4,902	125,981	9.7
2003	1,362,490	9,376	240,963	17.7
2004	1,433,339	11,110	285,527	19.9
2005	1,507,873	12,219	314,028	20.8

Source: Peter *et al*, 2009

The Communal Collection System involves the location of metal containers (skips) at designated sites known as (transfer stations), which are shared by a number of houses within that community. When the skips are full, they are transported and emptied at final disposal site by skip loading trucks.

2.7 Solid waste transport

Wastes are collected from one location and transported using vehicles, trains and ships to another location for processing. Solid waste transport has a wide range of social and environmental effects in urban areas such as noise pollution, air pollution, contribution to traffic congestion, involvement in traffic accidents, and the deposit of dirt and waste on the road network. Waste transportation activities especially in developed countries take place early in the morning and at night which can exacerbate the noise impact (Browne and Allen, 2007). Solid waste collection and hauling are estimated by

municipal planners in Malmo, Sweden, to account for 10–15% of the total freight transportations in the city, but due to the low average speed of vehicles used, and numerous stops during collection, the effect they have on congestion, air pollution, and noise is higher than that of other types of freight (Johansson, 2006). Waste transportation by road in recent times has come under severe criticism because of the danger it poses to the people and the environment. In London the Mayor has outlined policies to regulate the activities of waste transport by road to ensure that waste collectors operate efficiently to reduce the risk of air and noise pollution. Vehicles used in London to collect waste must meet appropriate standards and be operated efficiently to ensure that the routes are well planned and have regard to be sensitive of the day (Mayor of London, 2003).

2.7.1 Vehicles used in waste transportation

Waste collection vehicles are trucks specially designed to pick up smaller quantities of waste from point of generation and haul to landfill and other recycling or treatment facilities. These vehicles are often called garbage trucks, dustbin lorry and dump trucks. There are five different models of waste collection vehicles in the world.

These are:

1. Front loaders,
2. Rear loaders,
3. Side loaders, 4. Pneumatic loaders and
5. Grapple trucks.

In developing countries like Ghana, the rear loaders are mostly used in collecting the waste. The loaders have an opening at the rear that enables the waste collector to throw waste bags or empty the contents of the bins into it. Another popular system for the rear loader is a rear load container specially built to fit a groove in the truck. The truck will

have a chain or cable system for upending the container. The container full of waste will then slide into the hopper of the truck.

In the 1920s, the first open topped waste collection vehicles were made for the collection and disposal of waste, several complains of oduor and pollution of the environment by open topped trucks, covered vehicles were made to replace the open vehicles. These covered vehicles are used in developed countries. However, in many developing countries, the open topped waste vehicles are still used more often than the closed ones because of limited resources and the types of waste collection systems still used in collecting and transporting the waste.

2.8 Waste disposal

The problem of waste disposal in the world continues to grow with industrialization and population growth (Bassis, 2009). Since the beginning of time people have needed to find a way of disposing of their trash. In the 18th century, collectors were paid by individuals in England to carry their trash and discard it on the outskirts of town. Disposal in open pits became the first municipal cleaning program was in Philadelphia in 1757 (Kerala ENVIS Centre, 2009). Since then waste disposal in pits now called landfill has been developed to include different types of waste that cannot simply be dumped into a hole due to their effects on the environment (Bogner et al, 2007).

2.8.1 Early concepts of waste disposal

During the first century of the industrial revolution, the dominant methods of waste disposal were known as dilute and disperse. The amount of waste produced during this period was relatively small compared to present times and factories were usually located near streams and rivers to take advantage of the availability of cheap running water for the transportation of raw materials, finished goods and discharging of waste into the

streams and rivers. Because the population at this point in history was sparse and the quantity of waste being produced was small, dilute and disperse was used in removing waste from the immediate environment (Botkin and Keller, 2003). With increase in the amount of waste and population in the latter part of the 20th century, the concept of dilute and disperse became incapable of handling the increasing amount of waste being produced as a result of industrialization. Containers, be it simple tanks, trenches, waste metal drums had the potential to leak or break and spill their waste. According to Botkin and Keller (2003), some of these leaks resulting from waste disposal practices have led to the current situation whereby many people do not trust the government or industry to deal adequately with waste disposal in order to prevent public health hazards. It is no surprise then that no one wants to have a waste site situated around his or her home. This attitude is termed NIMBY- not in my back yard.

2.8.2 Modern trends

In modern times, the move has been to consider wastes as a resource. The idea is to consider all waste as reusable, thus there would be no such thing as waste. Waste when produced would be a resource to be used again. This is what has been termed the zero waste movement (Zero waste NewZealand, 2000). Zero waste forms the core of the concept called industrial ecology (Zero waste New Zealand, 2000). Industrial ecology is the study of relationships among industrial systems and their links to natural systems. Under this concept, industrial society will function just like the natural ecosystem whereby waste produced by one part of the system becomes a resource for another section of the system (Kelly *et al*, 2002)

The dominant concept today however in the management of waste is integrated waste management (IWM), defined as a set of management alternatives that include reuse, source reduction, recycling, composting, landfill and incineration (Ibid, 2003). The

ultimate aim of reuse, source reduction and recycling is to cut down the quantity of municipal waste ending up in landfills and incinerators.

Generally, conditions of waste disposal in Ghana are similar to those in many developing countries within the tropical climates. The overwhelming majority of landfills in Ghana are open dumps even though these are strongly discouraged in the national sanitation policy. The most feasible options for solid waste disposal (SWD) (Charles, 2007) are:

- Controlled dumping,
- Sanitary land filling,
- Composting, and
- Incineration

Complex systems for waste disposal that are coupled with energy recovery such as gasification and pyrolysis are not considered to be financially and technically sustainable in Ghana and are thus not considered. (Mensa and Larbi, 2005).

2.9 Methods of waste disposal

There are many different methods of disposing of solid waste in the world but the most common methods used in Ghana and other parts of Africa are landfill, open dumping and incineration. Landfill is the most common and probably accounts for more than 90 percent of the nation's municipal refuse even though landfills have been proven contaminates of drinking water in certain areas. The most common methods of disposing solid waste are described below:

2.9.1 Landfill

Disposing of waste in landfill involves burying the waste in pits and this is the most common practice in most countries. It is the most cost effective method of disposal, with collection and transportation accounting for 75 percent of the total cost **(**Bassis, 2009**)**. In a modern landfill, refuse is spread thin, compacted in layers and covered by a layer of clean earth. Pollution of surface water and groundwater is minimised by lining and contouring the fill, compacting and planting the uppermost cover layer, diverting drainage, and selecting proper sites not subject to flooding or high groundwater levels. The best soil for a landfill is clay because clay is less permeable than other types of soil. (Mensa and Larbi, 2005). Materials disposed off in a landfill can be further secured from leakages by solidifying them in materials such as cement, fly ash from power plants, asphalt, or organic polymers.

A properly-designed and well-managed landfill can be a hygienic and relatively inexpensive method of disposing of waste materials. Older, poorly-designed or poorly-managed landfills can create a number of adverse environmental impacts such as wind-blown litter and generation of liquid leachate. Another common byproduct of landfills is gas (mostly composed of methane and carbon dioxide), which is produced as a result of anaerobic break down of organic waste. This gas can create odour problems, kill surface vegetation, and is a greenhouse gas

2.9.2 Open dumping

Open dumps was a popular method of waste disposal in the early parts of the 20th century. This involved disposing the waste in open dumps without any cover or protection. Dumps were usually located in areas where there was land in abundance. A common site for open dumps is abandoned mines, quarries, swamps and hillsides. The

waste is usually piled up as long as the equipments being used can manage to move in and out of the dumpsite. Open dumps are popular in developing countries as a means of waste disposal (Tchobanogblous *et al*, 1993). It is practised in the households on a smaller scale and periodically burned to reduce the volume of waste and in some instances it is levelled and compacted. This is a common practice in Ghana.

2.9.3 Incineration

Incineration is another method of solid waste disposal. Incineration is a method of burning waste that is combustible at high temperatures in the range of 1000 degrees Celsius in other to reduce the waste to ashes. Incineration is more expensive but a safer method of disposal than landfills **(**Bassis, 2009**)**. Modern incinerators are designed to destroy at least 99.9% of the organic waste material they handle. Garbage burned in incinerators can poison air, soil, and water. Incineration converts waste materials in to heat, gas, steam and ash. Communities near incinerators have objected to them because of fears about possible emissions of gaseous pollutants (Bach *et a*l, 2009**)**.

In Ghana the national policy recommends small scale incineration plants for the treatment and disposal of health care and hazardous wastes. In most towns with health facilities small incinerators have been built as part of the health provision infrastructure. These facilities involve simple designs with lateritic bricks, cement blocks and metal. Local firewood is the most common energy source and the facilities are easily operated and maintained by environmental health staff of the District Assemblies. These simple incinerators have provided several years of service in dealing with relatively small quantities of hazardous hospital wastes. However, in reality many of such facilities have no environmental controls and often comprise nothing more than combustion of medical and chemical waste in an oven or open pit

(Mensah and Larbi, 2005)

2.9.3 Recycling Methods

Recycling involves the collection of used and discarded materials and processing these materials to make them into new products. It reduces the amount of waste that is thrown into the community dustbins thereby making the environment cleaner and the air fresher to breathe (Lave et al, 1999). Waste recycling has some significant advantages such as less utilization of raw materials, reduces environmental impacts arising from waste treatment and disposal and makes the surroundings cleaner and healthier. Additionally saves on landfill space, money, and reduces the amount of energy required to manufacture new products (Tchobanogblous *et al*., 1993).

Table 4: Items that can be recycled

Some items that can be recycled or reused	
Paper	Old copies
	Old books
	Paper bags
	Newspapers
	Old greeting cards
	Old cardboard box
Plastics	Containers
	Bottles
	Bags
	Sheets
Glass and Ceramics	Bottles
	Cups
	Plates
	Bowls
Miscellaneous	Old cans
	Utensils
	Cloths
	Furniture

Source: Tchobanogblous *et al*., 1993

Most of the garbage generated in the household can be recycled and reused. Organic kitchen waste such as leftover foodstuff, vegetable peels, and spoilt or dried fruits and vegetables can be recycled by putting them in the compost pits that have been dug in

the garden. Old newspapers, magazines and bottles can be sold to the man who buys these items from homes (United States Environmental Protection Agency, 2007).

2.9.3.1 The role of the rag pickers in picking recyclables materials

Rag picking is considered the most menial of all activities and it is people who have no other alternative that are generally driven to it (Scheinberg *et al*, 2006). Rag pickers contribute a great deal to waste management as they scavenge the recyclable matter thereby saving the municipality of the cost and time of collecting and transporting this to the dumps (Dias, 2000). It is one of the focal points for the recycling of waste. In spite of all the dangers that he/she faces, goes unrelentlessly picking through the garbage bin, looking for waste that could be useful to him (Eerd, 1996; Aziz, 2004). He/she sells all the material he picks to the whole sellers and retailers who in turn sell it to the industry that uses this waste matter as raw material.

The main items of collection are plastics, paper, bottles, metals and cans.

2.9.4 Biological reprocessing

Waste materials that are organic in nature, such as plant material, food scraps, and paper products, can be recycled using biological composting and digestion processes to decompose the organic matter. The resulting organic material is then recycled as mulch or compost for agricultural or landscaping purposes. In addition, waste gas from the process (such as methane) can be captured and used for generating electricity. The intention of biological processing in waste management is to control and accelerate the natural process of decomposition of organic matter.

There are a large variety of composting and digestion methods and technologies varying in complexity from simple home compost heaps, to industrial-scale enclosedvessel digestion of mixed domestic waste. Methods of biological decomposition are

differentiated as being aerobic or anaerobic methods, though hybrids of the two methods also exist.

The energy content of waste products can be harnessed directly by using them as a direct combustion fuel, or indirectly by processing them into another type of fuel.

2.9.5 Composting

Composting is a biological process in which micro-organisms, mainly fungi and bacteria, convert degradable organic waste into humus-like substance. This finished product, which looks like soil, is high in carbon and nitrogen and is an excellent medium for growing plants. The process of composting ensures that the waste produced in the kitchens is not carelessly thrown and left to rot. It recycles the nutrients and returns them to the soil as nutrients. Apart from being clean, cheap, and safe, composting can significantly reduce the amount of disposable garbage. The organic fertilizer can be used instead of chemical fertilizers and is better when used for vegetables. It increases the soil's ability to hold water and makes the soil easier to cultivate. It helps the soil to retain more of the plant nutrients (Mensah and Larbi, 2005).

Generally, conditions in Ghana are very conducive for composting in terms of the waste composition and weather conditions. However, composting has never flourished as an option for refuse treatment and disposal. Most local authorities feel, based on local experience, that the running costs of composting plants are excessive and unjustifiable (Mensah and Larbi, 2005). The only known large composting plant in Ghana was built with external donor support and commissioned in the early 1980s. During its early years of operation the plant was useful in helping reduce the volume of waste. However, high maintenance costs adversely affected its sustainability. In the last few years most of the mechanical components have been decommissioned and the plant currently operates only for demonstration purposes.

CHAPTER THREE

3.0 METERIALS AND METHODS

This chapter describes in detail the study area, the four different models used for the study, the sampling techniques and sampling method used, sources of data and the method of data collection

3.1 The study area

The study was conducted in the Kumasi metropolis, the second largest city in Ghana. Kumasi is the capital of Ashanti Region one of the fastest growing urban cities in Ghana with an estimated population of 1,610,867 in 2006 and a projected population 1,889,934 by 2009(Ghana Statistical Service, 2006). Kumasi is also known as the garden city of Ghana, located in the transitional forest zone and is about 270 km north of the national capital The economic activities in the metropolis are grouped in to three- the agricultural sector, the industrial sector and the services sector. The city lies between latitude $6^0\ 35^1$– $6^0\ 40^1$ N and longitude $1^0\ 30^1$–$1^0\ 35^1$ W. The elevation ranges between 250 and 300 m above sea level with an area of about 254 km^2. The average minimum temperature of Kumasi is about 21.5^{o}C and a maximum average temperature of 30.7^{o}C. The average humidity is about 84.16% at 0900 GMT and 60% at 1500 GMT.

The Waste Management Department (WMD) has the responsibility of overseeing the activities of the companies sub-contracted for household waste collection in the metropolis.

3.2 Research approach

To determine how descriptive and explanatory conclusions should be drawn, it is very appropriate to consider specific approaches to use in the study. Case studies are therefore important and suitable in researching complex situations like processes and

behaviors. Therefore to determine and recommend effective waste logistics for the Kumasi metropolis it is important to understand the current waste collection service delivery systems and flows in the city. In order to achieve the purpose of this study, two approaches were adopted. These were:

1. Mapping out the waste logistics flows in the city
2. Use of structured questionnaires and personal interviews.

3.3 Mapping out the waste logistics flows in city

In this study four different waste logistics models were developed and used to study waste collection logistics systems in the Kumasi metropolitan area. These models served as case studies in gathering data from waste collection points, routes and disposal sites within KMA area to develop and recommend effective waste logistics system for the KMA and also to map out the different models of waste collection, transportation and disposal in the municipality. Models were used to describe the real system. System is an object or an organization of planned activities and models are used to provide deep understanding of the bigger system. The models are described below:

3.3.1 Model One

Model one is represented in Fig 1. It describes one complete system of waste logistics starting from the generation point to the landfill sites. The green small circles represent households, where the wastes are generated, collected and transported to a central collection point. The blue arrows indicate the flows from the public places to the central collection points using tricycles, wheelbarrows and head carrying of the waste to the central collection point. The red big circle is the central collection point where all the wastes from the public places are gathered before it is collected and transported to the landfill. The red arrow indicates the routs of the collection vehicles used to collect and

to transport the waste from the central collection point to the landfill sites. The blue oval shape represents landfill site where all the wastes collected from the central stations are deposited

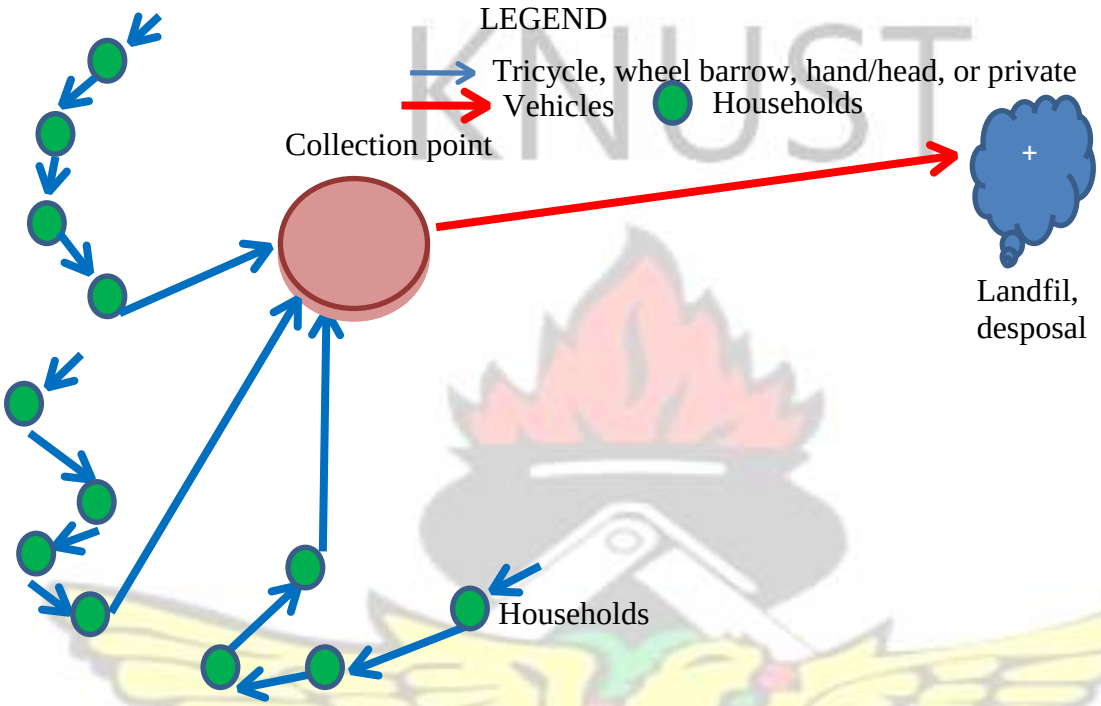


Fig 1: Waste collection from household and transport it to disposal site – Model I

3.3.2 Model Two

Model two is represented in fig 2. It is one of waste collection system used within the Kumasi Metropolitan sub metro. The small circles coloured green and yellow represent different households from different sections of a particular area, the blue arrow indicate the mode of collection to the collection point by the use of tricycle, wheel barrow and hand/head. The red big circles are collection points for each section in a particular area where all the waste from households are gathered for collection. The red arrows indicate the collection vehicle. The vehicle moves from one collection point to another collecting point to collect the waste. When the vehicle is full it is transported to the

landfill for disposal. This process is continued until all the waste from all the collection points are collected and transported to the landfill.

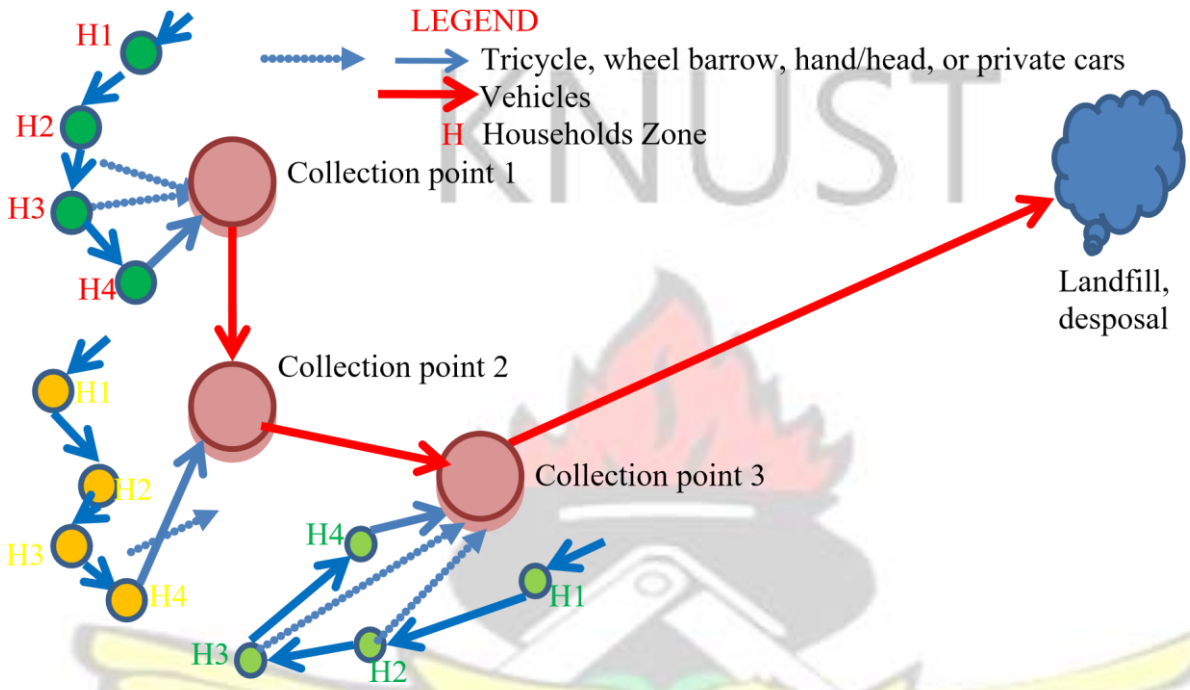


Fig 2: Waste gathered from household to collection point and transport to disposal site – Model II

3.3.3 Model Three

The model in Fig 3 is the communal waste collection system. This was the first collection system that replaced the open dumping system after city authorities were challenged to improve the systems of collection in the early 1980s (KMA waste management department). All the old dumping sides were transformed into central collection points where individual households take their waste to before it is transported to the final disposal site. The red circle in the figure 3 is the central collection point where all the houses around this location dispose off their daily waste. The small circles represent the houses where two or more households are living together. This system of

collection is used in the low and middle income areas because of the poor road network linking the houses together. The blue arrow represents the first flow of waste from the houses to the central collection point. The red arrow is the final flow of the waste from the collection points to the disposal sites using vehicles.

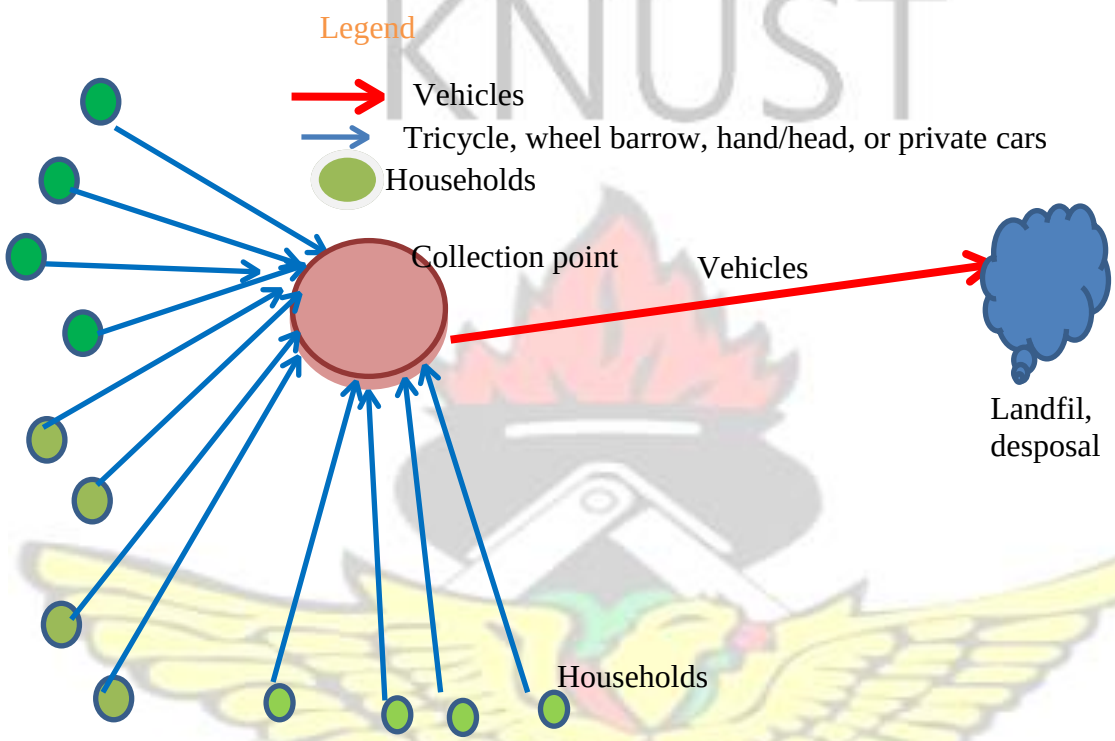


Fig 3: Waste collection from central collection point and transport to disposal sites – Model III

3.3.4 Model Four

This model is popularly called door-to-door waste collection service. It is one of the new waste collection systems being implemented by KMA in most parts of the city especially in first class or high residential areas, restaurants, hotels and corporate institutions. In this model only vehicles are used for the collection of the waste at the of point generation to disposal site. The red arrow in fig 4 represents the vehicle moving from one house to another until the car is full before it takes it to the landfill site.

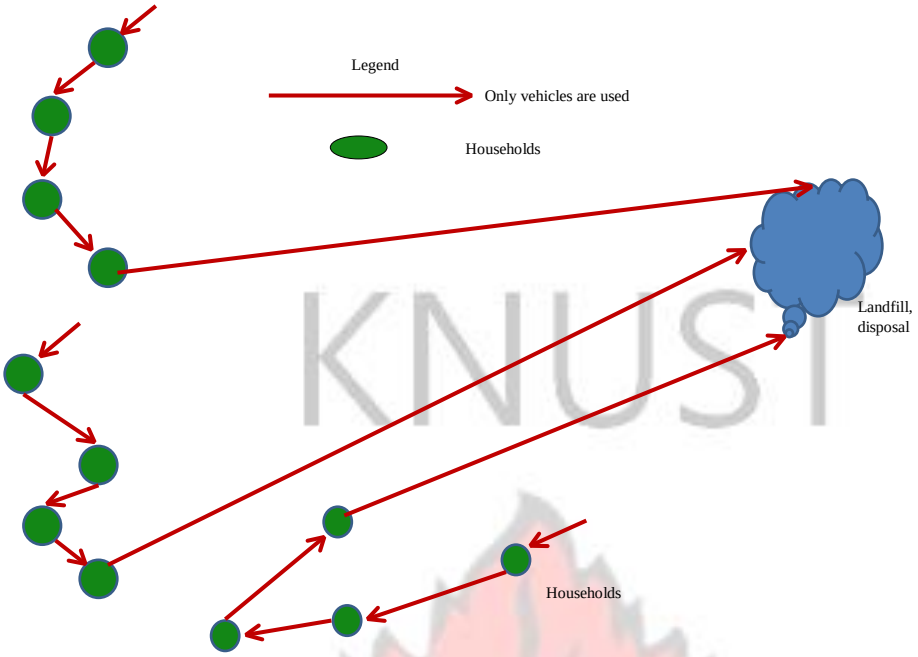


Fig 4: Waste collection from household using only vehicles to collect and transport it to disposal site – Model IV

3.4 Identification of models in the sub-metros of the Kumasi Metropolitan area

The KMA has 10 sub metropolis. They include: Bantama, Suame, Tafo, Subin, Manhyia, Asawasi. Kwadaso, Oforikrom, Asokwa and Nhyiaso. There are seven private waste collection companies that are engaged by KMA working in the 10 sub metropolitan areas to collect and dispose of waste within the Kumasi area. The private companies include: Zoomlion, Meskworld, ABC, Anthoco, Zak-M, Waste group and Kumasi Waste Management. The waste contractors are working in separate sub metropolis. The Kumasi waste management department monitors and supervises the activities of all the waste companies in the metropolitan area. The Kumasi waste management department was the first to be contacted and shown the four models to identify which of the models are used in each of the sub metropolises. Two of the

models were identified as the popular ones used in the city. These models were the door-to-door collection model and the communal collection model in fig 3 and 4 respectively. The department indicated that they monitor and supervise the work of the private waste collection companies contracted based on the terms, structures and facilities they have put in the system. The companies are to collect and dispose of the waste. The private waste companies were contacted for further identification of the models used in their respective sub metros. Initially, most of the companies thought their activities were going to be audited and would not assist researcher but after series of interactions some of them opened up. When the four models were describe to management of private waste collection companies at a meeting organised by KMA, they identified these models in table 5 as ones they implement in their coverage areas.

Table 5: Identification of Models by waste companies

Private collecting company	Name of sub metro	Models used
Waste group Ltd	Kwadaso	One and four
Kumasi Waste Management Ltd	Nhyiaso	Three and four
ABC waste	Oforikrom	Two and four
Sek- M	Asokwa	Three and four
Zoom lion Ghana	Subin, Tafo and Asawasi	One, three and four
Mexwell waste company	Bantama and Manhyia	Three and four
Anthoco waste company	Suame	Three and four

Source: Authors Field report, July 2009

3.5 Tracing of the models from each sub-metro

Dates and time were scheduled with the management of the companies that allowed the researcher to follow their staff to the field to trace these models in their working areas. In each of the sub metropolitan area the Global Positioning System (GPS) was used to trace the two models that were identified as the most popular ones used in the collection of waste. This started as early as 5am in the morning and ended at 4 pm throughout the period of September 2009. The researcher worked with each company for a maximum of three to four days. The coordinates of all the collection points, disposal points, the distances from one point to another, the routes that the vehicle used and vehicle waiting time or time used in collecting the waste from one point to another were located. Also the waste collectors and the drivers who were at the central collection points were all interviewed. Some households shared their frustrations most especially those close to the collection points. At the disposal points, some of workers ask questions to be sure that the research is not investigating them. All the activities that took place at the logistics points were observed.

3.6 Sampling technique and sample method

The first targeted population of interest for this study was waste generators (households and public places) in the KMA. The sampling unit was households, defined for this study as a group of people who eat from the same pot and share common resources. The households are stratified into income groups based on the characteristics of the housing structures as low income, middle income and high income. The areas that constitute these income zones were in the communities that the four waste logistics models were traced. These communities were determined by the duty roaster or schedule of the drivers on a particular day of that company. The houses within these areas were randomly sampled to contain several households. A total of 180 households were randomly sampled using the house numbers. When a house was sampled in an area and it happened that the household declined to respond to the questionnaire, it was replaced by the next house after that house. The sampled communities were characterised into the main income groups as low, medium and high critically considering all the four models. Three communities were randomly selected from all the income groups. The communities that were selected for the low income groups comprised Adukrom, Abuabu and Suame trotro(Old Suame). The medium income areas are Agric Nzema, Patasi and Nkontwima. The high income communities are Ayiduasi New Site, Daban New Site and KNUST. Table 6 shows the sampled communities and the model used for collecting waste in the area

Table 6: communities sampled for the household survey

Sub metropolitan	Community	Model used	Sample size
Kwadaso	Agric Nzema	IV	20 HH
	Patasi	IV	
Nhyiaso	Daban	IV	20 HH
Oforikrom	KNUST	II	20 HH

	Ayiduasi New site	IV	20 HH
Tafo	Adum	I	20 HH
Asawasi	Adukrom	III	20 HH
	Abuobu	III	20 HH
Suame	Suame Trotro	III	20 HH
	Nkontwima	IV	20 HH

Source: Authors field survey, 2009

The second target group for this study is the waste collectors. These are institutions involved in collecting and disposing of waste within the metropolitan area. They include all the private waste collection companies operating within the Kumasi metropolitan area and KNUST sanitation department. A total of six private waste collection companies in the city and the KNUST sanitation department were interviewed

3.7 Data Analysis

Two categories of data were collected from the field. The first set of data was collected using Global Positioning System (GPS) from seven sub metropolis in the Kumasi area. These are the latitude and longitude of the waste logistics points within the Kumasi area and the data was analysed using the arc GIS software to plot all the coordinates on a digital map of Kumasi. The GIS showed all the flows, points and the distances from one collection point to another of all the four waste models that were traced in the field. A map was developed to determine all the waste location points and the disposal points in the Kumasi metropolitan area. The GPS provides continuous three dimensional positions. The second data from the questionnaires on households and the waste collection companies were analysed using SPSS and descriptive statistical tools. Statistically, t – test was used to compare the means of the four waste collection models at 95% confidence level to select the most suitable model for the city of Kumasi.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Introduction

The chapter presents discussions of the results of the study. The results are in two categories. The first part of the results is the response of households and the private waste collection companies to recommend an effective waste logistic system for Kumasi by comparing the four different waste logistic models in the metropolitan area. The second part of the results is from the four different waste logistics models collected using GPS (global positioning system) and the GIS (Geographic Information System) was used to plot the coordinates of waste logistics points on the digital map of Kumasi to represent the waste logistics map of the Kumasi metropolitan area.

These two results are also presented and discussed in this chapter.

4.2 Waste generators (Households) Socio-demographic characteristics

The results of the socio-demographic characteristics of the household waste generators sampled for the studies are shown in Table 7. The results are based on a sample of 180 completed questionnaires in October and November 2009. The sample is made up of 48 males representing 26.7% of the respondents and 132 females, representing 73.3% of the respondents. The high percentage of female respondents is due to the fact that females are mostly responsible for household chores such as cooking, fetching of water, cleaning of the homes and disposal of waste in Ghanaian culture. The average age of the respondents for the sample is 31.7 years with a minimum age of 14 years and a maximum age of 78 years (Appendix D). The average age suggests; that most of the respondents sample is within the age bracket of 22 years to 46 years, considered as the youth.

In education, 36.1% of the respondents had senior high school education, about 22.2% of the respondents had junior high school education, 21.7% had tertiary education, 13.9% of the respondents had no education and 6.1% of the respondents had primary education. The results on education levels with majority attaining junior and senior high school certificate (average of 7 years of education) is comparable to the national average in Ghana of 5 years of education with a standard deviation of 5.4 as shown in the Ghana living standard survey 4 (Ghana statistical service, 2000).

Table 7: Socio-demographic characteristics of respondents

Variable	Options	Frequency	Percentages (%)
Gender of respondent	Male Female	48 132	26.7 73.3
Educational level of respondent	Primary	11	6.1
	Junior High	40	22.2
	Senior High	65	36.1
	Tertiary	39	21.7
	No education	25	13.9
Marital status of the respondent	Married Single	110 65	61.1 36.1
	Divorced	4	2.2
	Others	1	.6
House hold size	1 – 3	33	18.3
	4 – 6	80	44.4
	Above 7	67	37.2

Source: Authors field survey November, 2009

In table 7 44.4% of the respondents are within the household size of 4-6, 37.2% of the respondents are within the household size above 7 members and 18.3% of the respondents are within the household size 1-3. The high percentage of the household size 4-6 and above 7 emphasises the fact that the Ghanaian population is increasing and

this explains the fact that waste generation in the city is expected to increase by 15% by the year 2010(Waste Management Department -KMA 2008).

4.3 Waste generation quantities

Figure 5: Bar graph showing amount of waste collected per day in the Kumasi metropolitan area

Figure 5 shows the amount of waste that is collected daily by the city authorities. According to Style Owusu, a private waste management company and the Zoomlion Company, who are in charge of managing the landfills in the city indicated that an average of 1200 tonnes of waste is collected everyday. This explains why the KMA waste management reports showed that about 80-85% of the total amount of waste generated in the city is collected per day.

4.4 Waste separations

Table 8 shows how households handle waste in their homes. The studies revealed that majority of the households in Kumasi do not separate their waste. When they were asked whether they separate their waste, about 87% of the respondents answered negatively and about 12.8% respondents answered positively. About 50% of the respondents who answered negatively would not be willing to separate their waste stating that it would increase the existing fee the waste collection companies are charging. When they were asked again whether they would need incentives as source of motivation to separate waste, about 36.9% of the respondents still insist that they would not separate their waste. The study revealed that, about 63.1% of Ghanaian household waste generators are willing to separate their waste if they are motivated to do so.

Table 8: Waste separation

Statement	Options	Frequency	Percentages (%)
RESPONSE FROM HOUSEHOLDS			
Do you source/separate the waste	Yes	23	12.8
	No	157	87.2
How do you separate them	Food waste	16	8.9
	Non food waste	7	3.9
Would you be willing to separate your waste	Yes	67	42.7
	No	90	57.3
Do you need incentives to separate waste	Yes	99	63.1
	No	58	36.9
RESPONSE FROM PRIVATE WASTE COMPANIES			
Do you encourage source separation of the waste	Yes	2	28.6
	No	5	71.4
Would you be willing to give incentives for source separation of the waste	Yes	-	-
	No	7	100.0

Source: Authors Field survey, November 2009

However, when the private waste collection companies were asked as to whether they encourage source separation of waste at the households, about 71.4% of private waste companies responded negatively and 28.6% respondents answered positively. All the waste collection companies were not willing to provide or give incentives to households to encourage source separation of the waste. They indicated that it would increase the cost of collection.

4.5 Waste collection

Table 9 shows the result on the state of waste collection systems presently functioning in the metropolis. The result revealed that 91 respondents representing about 50.6% of the sample size were in favour of someone coming to their home/residence to pick or collect the waste. Eighty-nine (89) respondents representing 49.4% of the sample were

also of the view that, they dispose of their waste by themselves at a communal collection points. These results can be compared with the Kumasi waste management department report which indicated that, there are two major systems of waste collection used in collecting waste in the metropolis (House-to-house collection and communal collection). The House to house collection is used in the high and middle income residential areas while the communal collection system is used in slum communities or low income areas where the road network is not accessible. The study also revealed that Zoomlion, a private waste collection company is the most popular waste management company in the metropolis because majority of the respondents about 11.7% said that it is Zoomlion private waste management company that collects waste in their community.

Respondents whose wastes were not collected from their homes, when they were asked how often they dispose off the waste, about 75.3% of the respondents said that they dispose of their waste daily at the communal collection points, 15.7% of the respondents dispose off their waste once every week at the communal collection points and the other respondents representing 9% dispose off their waste by burning and dropping the waste in pits. Sixty-seven 67.4% of the respondents said that children carry the waste to the disposal site (bola), 16.9% of the respondents said that women carry the waste to the disposal site and 15.7% of the respondents said that the house maid disposes the waste to the collection points.

Table 9: Waste collection

Statement	Options	Frequency	Percentages (%)
Does someone come to collect the waste	Yes	91	50.6
	No	89	49.4
If yes, who or which company collects the waste	ABC	10	5.6
	ZOOMLION	21	11.7
	kNUST	16	8.9

	KWM	17	9.4
	ANTHOCO	9	5.0
	Bola man	1	.6
	KWML	16	8.9
	Anima rarer	1	.6
How often do you dispose waste	Once daily	67	75.3
	Once every week	14	15.7
	Others	8	9
Who carries the waste bins to the disposal site	Children	60	
	Woman	15	67.4 16.9
	Maid	14	15.7

Source: Authors Field survey, November, 2009

4.6 Logistics for waste collection at the households

Effective waste collection and safe keeping of waste at the household is dependent on the kind of materials that are used to collect and keep the waste. Table 10 reveales that, about 54.4% of the respondents have waste bins in their homes to keep waste whiles 45.6% of the respondents do not have waste bins in their homes but keep their waste in jute sacks, old broken buckets and baskets. When they were asked where they keep the waste bins in the house, about 32.8% of the respondents said that they keep the waste bins at the backyard of the house about 26.1% keep it at the gate, about 27.8% keep it inside the yard or compound and 6.7% of the respondents keep their waste bins in the kitchens. They were further asked whether they have received education on how to use these waste bins. About 97.8% of the respondent's received no education while only 2.2% of the respondents received education.

Table 10: logistics for waste collection

Statement	Options	Frequency	Percentages (%)
Do you have waste bin	Yes No	98 82	54.4 45.6
How do you keep your waste	Jute sacks Old baskets Broken buckets Others	15 8 31 27	8.3 4.4 17.2 15.0
Where do you keep waste bin in the house	At the backyard At the gate At the yard At the kitchen Others	59 47 50 12 12	32.8 26.1 27.8 6.7 6.7
Have you received education on how to handle and dispose of waste	Yes No	4 176	2.2 97.8

Source: Authors Field survey, November, 2009

The study also revealed that the private waste collection companies supplied waste bins to households that have registered under the house-to -house collection system but did not supply waste bins to households under the communal collection system. All the private waste collection companies except Zoomlion agreed that they have not trained households on how to use and keep the waste bins at their homes.

4.7 Amount paid for collection or dumping of waste by Households

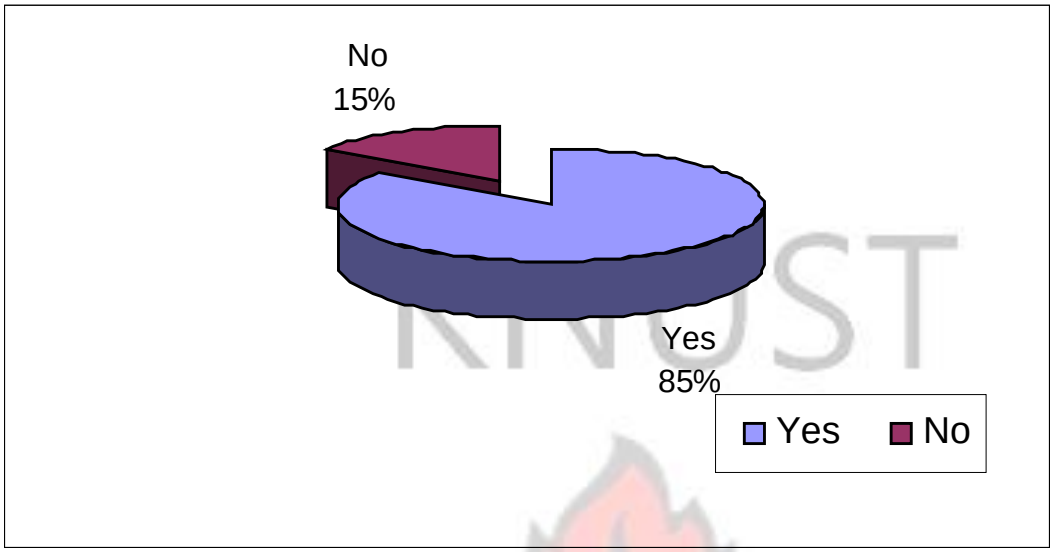


Fig 6: A pie chart of whether households pay for waste collection/dumping

Figure 6 shows that 85% of the respondents paid for collection or for dumping of their waste whiles 15% of the respondents do not pay for dumping of their waste at the collection points. The minimum amount paid for the house to house collection per month is 4 Ghana Cedis and the maximum is 20 Ghana Cedis. For the communal collection system the minimum amount paid per month is 3 Ghana Cedis and the maximum is 5 Ghana Cedis.

Table 11 shows that the waste companies spend a minimum of 6,000 Ghana Cedis and a maximum of 30,000 Ghana Cedis every month in collecting and disposing of the waste in the metropolis. The closest collection point to the disposal site is about 5 km to the landfill and farthest collection point to the disposal point is about 15km. The cost of fuel was the major concern of most of the waste collection companies and about 70% of the total cost of collection of waste was attributed to the fuel cost.

However, none of the companies had a programme in place to reduce the cost of fuel and use of shorter distances (alternative routes) from collection points to disposal sites

Table 11: Cost of waste collection

Statement	Minimum	Maximum	Standard deviation
How much do you spend every month in collecting the waste	6000.00	30000.00	9180.75410
How far is the collection points from the disposal site	5.00	15.00	3.70135

Source: Authors Field survey November, 2009.

4.8 Waste transportation

Waste transport includes all the processes involved in moving the waste from its original generation point to its final disposal point. The results shown in table 12 indicate how waste is transported from the homes to the central collection point. About 89.9% of the respondents hold or carry the waste on the head to the central collection point, about 5.6% of the respondents used wheel barrows to convey their waste to the central collection points, 1.1% of the respondents used the tricycle (motor king) to convey their waste to the central collection point and about 3.4% used their cars to convey their waste to central collection point. When asked how far the central collection point from their homes is, about 52.8% of the respondents said that the central collection point was more than 50m from their homes, 16.9% of the respondents said that it was about 50m from their homes. 15.7% of the respondents said that it was about 30m from their home and 14.6% of the respondents said that it is about 10m close their homes.

The results revealed that all the waste collection companies used the skip and the compaction trucks in collecting and transporting waste from the collection points to disposal sites. The companies used the skip trucks to convey waste from the central collection points to the disposal sites whiles the compaction trucks are used to collect

waste from one house to another house before it is conveyed to the disposal site. Meanwhile, Zoomlion Company has developed other transportation alternatives for collecting and disposal of waste. These are the bicycles and tricycles with buckets and fitted either with motor or without motor. They are used to gather the waste from the units to the central collection points before it is conveyed by a collection truck to the disposal site. When the collection companies were asked how many of these vehicles they used in their coverage area, majority of the companies used two or three of these vehicles and most of these vehicles were in bad shape. It was observed that most of the vehicles used for the collection and disposal of waste frequently break down. This explains why these companies are unable to collect and dispose off wastes as required by them. However, Zoomlion waste management company had a fleet of new vehicles and well trained staff to maintain the vehicles at their workshop. They even had a mobile workshop van to follow up vehicles in the field to solve minor technical faults.

Table 12: Waste transport

Statement	Options	Frequency	Percentages (%)
By what means does the person carry the waste to the collection point (bola)	Head carrying	80	89.9
	Wheel barrow	5	5.6 1.1
	Tricycle	1	3.4
	Cars	3	
How far is the disposal site from home	10m	13	14.6
	30m	14	15.7
	50m	15	16.9
	Above 50m	47	52.8

Source: Authors Field survey November, 2009

4.9 Waste recycling and reuse

Recycling involves the collection of used and discarded materials, processing these materials and making them into new products. Certainly, this is not the case in Kumasi. The study revealed that all the waste collection companies understand the concept of waste recycling and reuse but none of the companies recycles or reuses the waste they collect. All the waste companies transport waste to landfill centres. The study revealed that none of the private waste collection companies neither owns a recycling plant nor an energy/ nutrient recovery plant. However the waste collectors employed by the private companies and rag pickers at the landfill collect discarded plastics and metals and sell these materials to retailers and wholesalers for some income. These materials are gathered by the retailers and the wholesalers for transporting to Tema – the industrial hub of Ghana for recycling.

Table 13: Waste recycling and reuse

Statement	Option	Frequency	Percentage
From the transfer stations where do you send the waste?	Landfills centre	7	100.0
Does your company have recycling unit?	No	7	100.0
Does your company have a Energy/Nutrient recovery centre?	No	7	100.0
Does your company own a landfill?	Yes	1	14.3
	No	6	85.7
If your company has no landfill where do you dump your waste?	KMA landfill (managed by Syle Owusu) and Zoomlion LF	6	85.7
Are there ways we can reuse the waste?	Yes	6	85.7
	No	1	14.3

If yes how?	Recycling	1	14.3
	Energy generation	1	14.3
	Recycling and Energy generation	1	14.3
	Fill soil excavation (land reclaiming)	3	42.9

Source: Authors Field survey, November, 2009

4.10 Waste disposal

Table 14 reveals that about 4 of the waste companies representing 57.1% of the response from the private waste companies said that they paid fees for dumping waste at the waste disposal site, about 42.9% of the waste companies also said that they paid fees for disposing off waste at the landfill site through KMA deductions from the amount that is paid to the company for collecting the waste. When they were also asked about which activities are undertaken at the landfill site or at the disposal points, they all mentioned spreading, compaction, weighing, unloading and covering. They all agreed that there are queues at the landfill site and it is mostly caused by the breakdown of the heavy duty equipment that are used to spread and compact the waste. They also added that during the rainy season the landfill site becomes inaccessible because the area becomes muddy and the vehicles easily get stucked to the ground preventing other vehicles from reaching the disposal site.

Table 14: Waste disposal

Statement	Option	Frequency	Percentage
Do you pay fees before dumping waste	Yes	4	57.1
	No	3	42.9
What activities are undertaken at the disposal points	Unloading, weighing and spreading	1	14.3
	Spreading, compaction and covering	3	42.9

	Unloading and Spreading	3	42.9
Are there queues of vehicles at the landfill	Yes	6	85.7
	No	1	14.3
If Yes what is causing the queues	Spreading and compaction	6	85.7
	Rains	1	14.3

Source: Authors Field survey, November, 2009

4.11 Comparing the waste logistics models

The four different waste logistics models used in this study are compared based on the following results:

4.12 The Demographic characteristics of the four different models

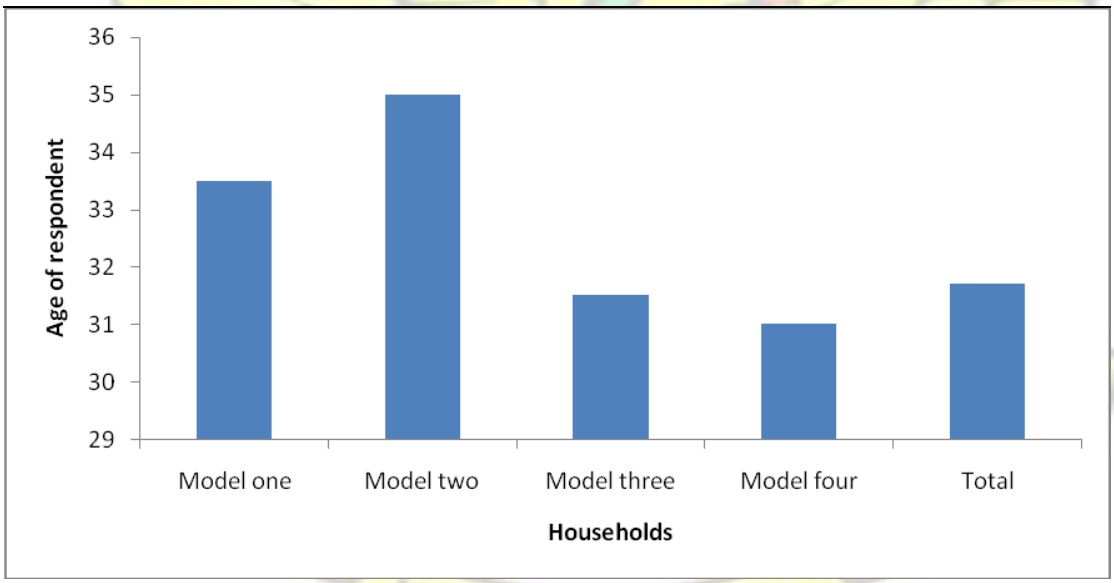


Figure 7: comparing the mean age of the respondents with regards to waste collection responsibility

Figure 7 is the average ages of the respondents of the four models. Statistically the mean ages of the four models were not significantly different from the average age of the total sample used. Therefore, most of the respondents are within the age bracket of 22 years to 46 years which is considered as the youth. These people are responsible for cleaning, collecting and disposal of waste in the Ghanaian cultural set up.

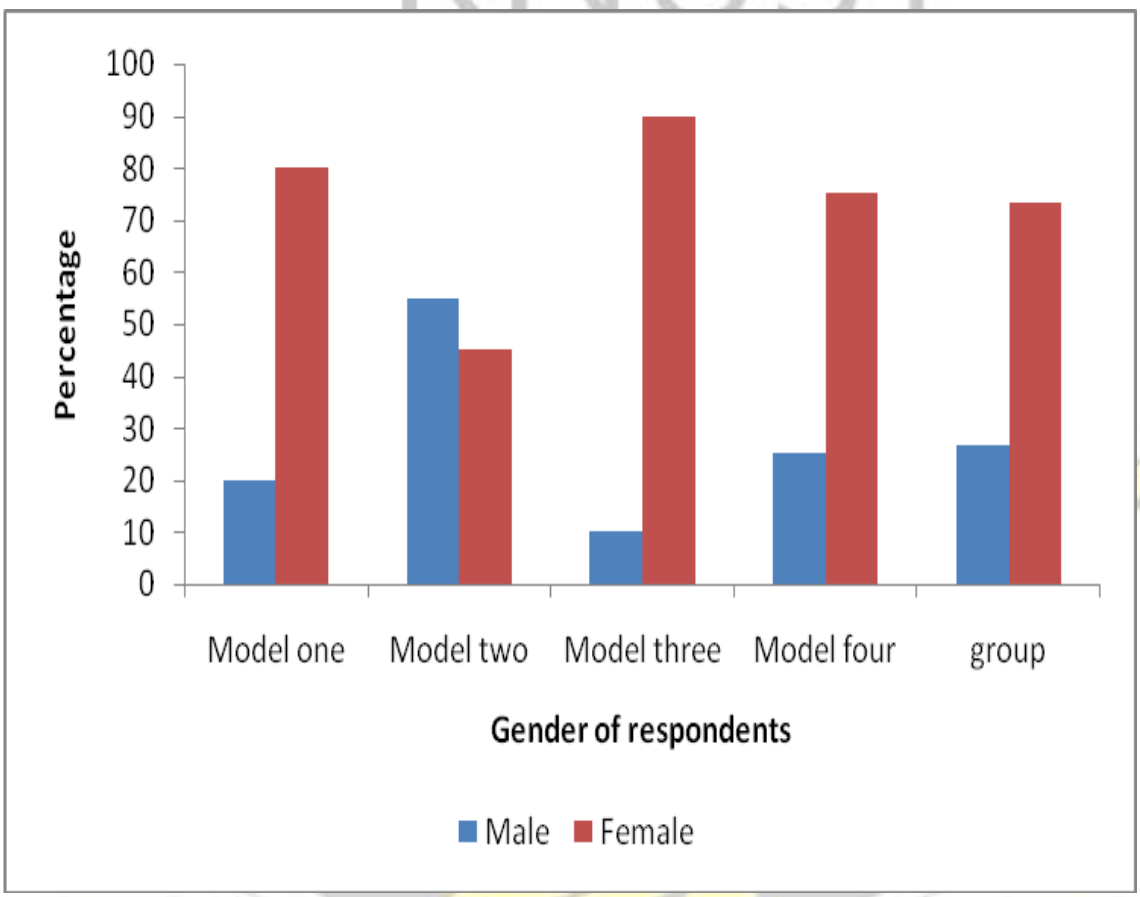


Figure 8: Comparing the gender of the respondents with regard to waste collection

Figure 8 shows that majority of respondents in model one, three and four are female while in model two the male respondents are in the majority. The reason is that, model two is the KNUST community which is a high learning institution and so most of the gender roles are challenged and men take up some household responsibilities as

compared to men in model one, three and four. Statistically, there are no significant difference between the models and the total

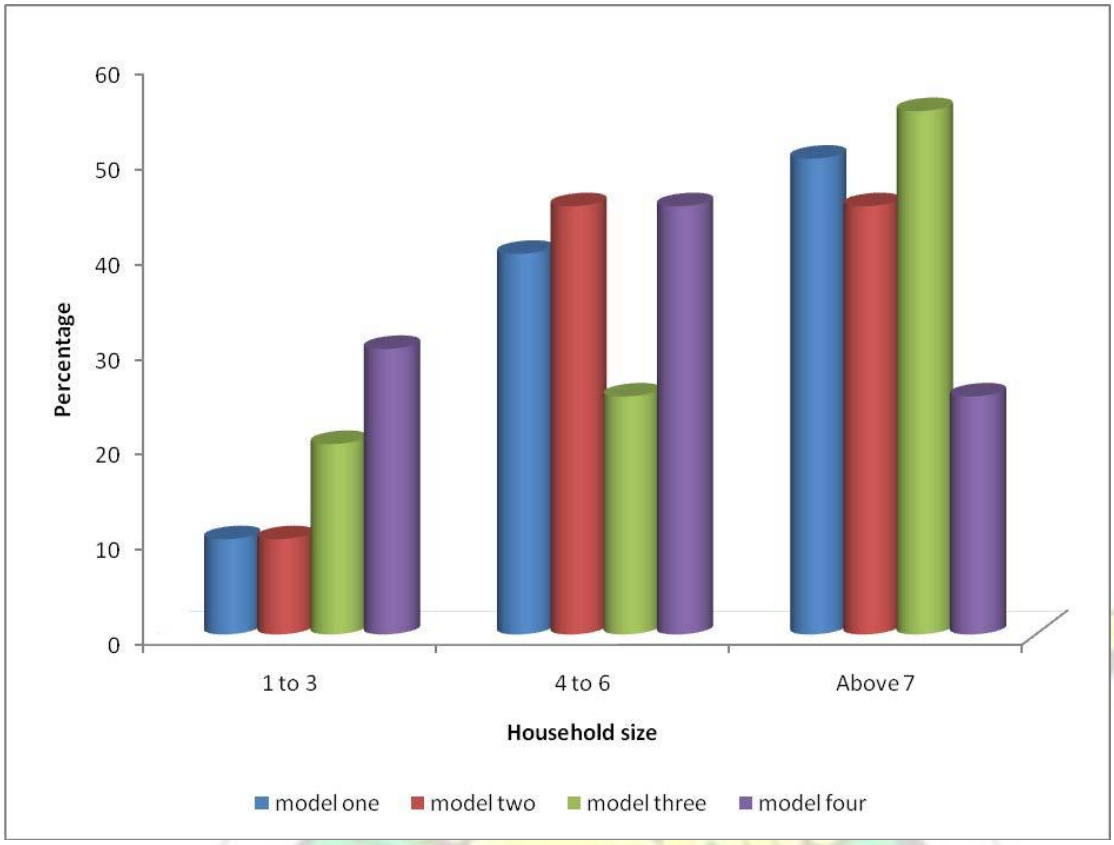


Figure 9: Household size and waste generations

Figure 9 compares the household size of the four models. Model three and one which are typical of low income areas, the household sizes are hihg because of the extended family system that still exists in these areas and birth control is still a problem. This suggests that more waste is generated from these two models. The results also showed that model two – the KNUST waste collection model also has a high household size. This is because some students stay with their relatives who are lecturers or staff of the university due to the acute accommodation problems on school campuses. In model

four, majority of the household sizes are between 3 and 6. This is because most of the residents in these areas are well educated and live in the high income areas.

4.13 Household waste handling

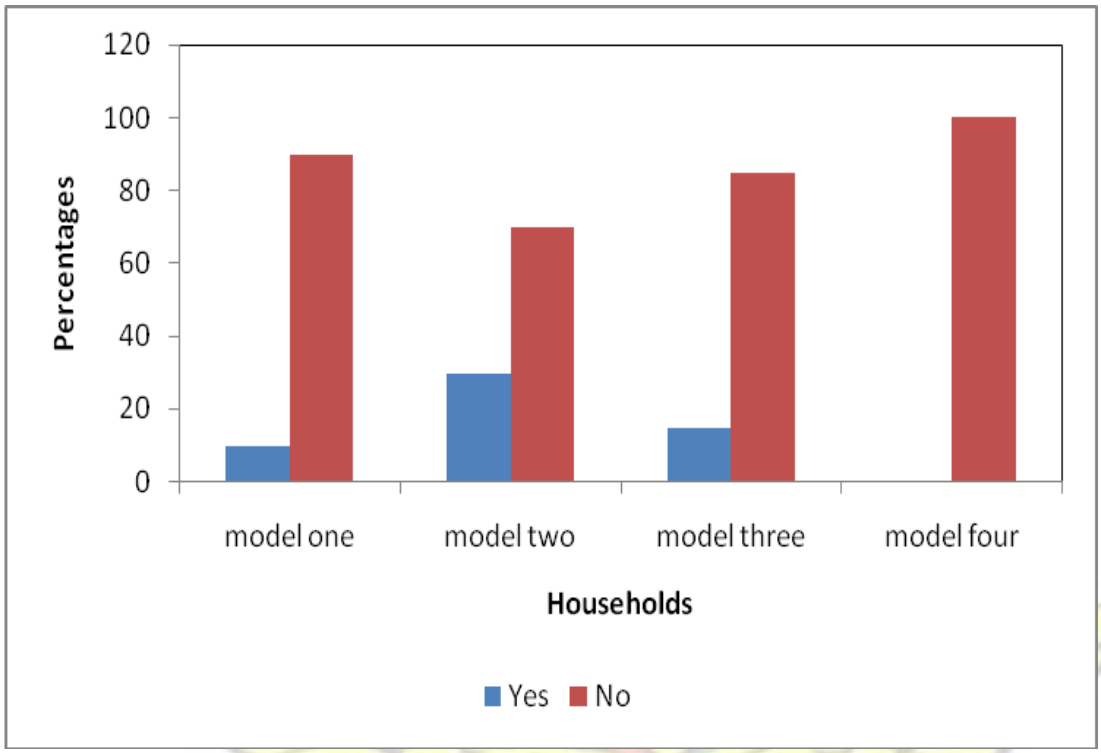


Figure 10: Household waste sorting

Figure 10 describes household waste sorting for the four models. The results indicated that, household waste sorting is not encouraged in our society. This is because the systems of waste collections are not designed to include source separation of waste and therefore adequate infrastructure are not provided to households to source separate the waste. In model four, because households are provided with one waste bin each and because there are no animal keepers in these communities, no sorting of the waste in these areas is done.. In model one, two and three, households are not provided with waste bins. Households purchase these waste bins for collecting and disposing of the waste. Animal keepers sometimes provide some households with collection materials

to reserve food waste for onward collection hence the low levels of waste sorting in model one, two and three.

4.14 Waste collection

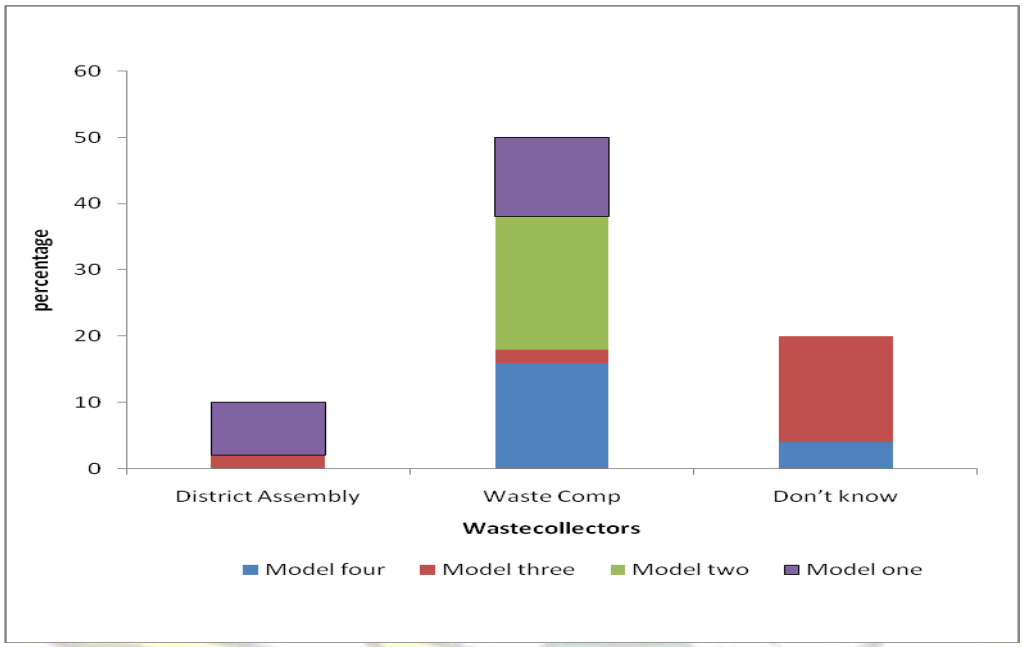


Figure 11: Stakeholders responsible for collecting the waste

The results in figure 11 show that when the households waste generators were asked who has responsible for collecting the waste in their locality, respondents in the model one and model two indicated that, they knew the city authority were responsible for collecting the waste. These were the district assembly (DA), the waste collection company (WC) and the university authority (U) but majority of the respondents in the model three (communal collection system) did not know (DK) the city authorities were responsible for collecting the waste in their locality. This explains why some central containers can get full and left standing there for about a week and people keep dumping waste around the containers, turning the surrounding into an open dumping ground.

4.14.1 Regular waste collection

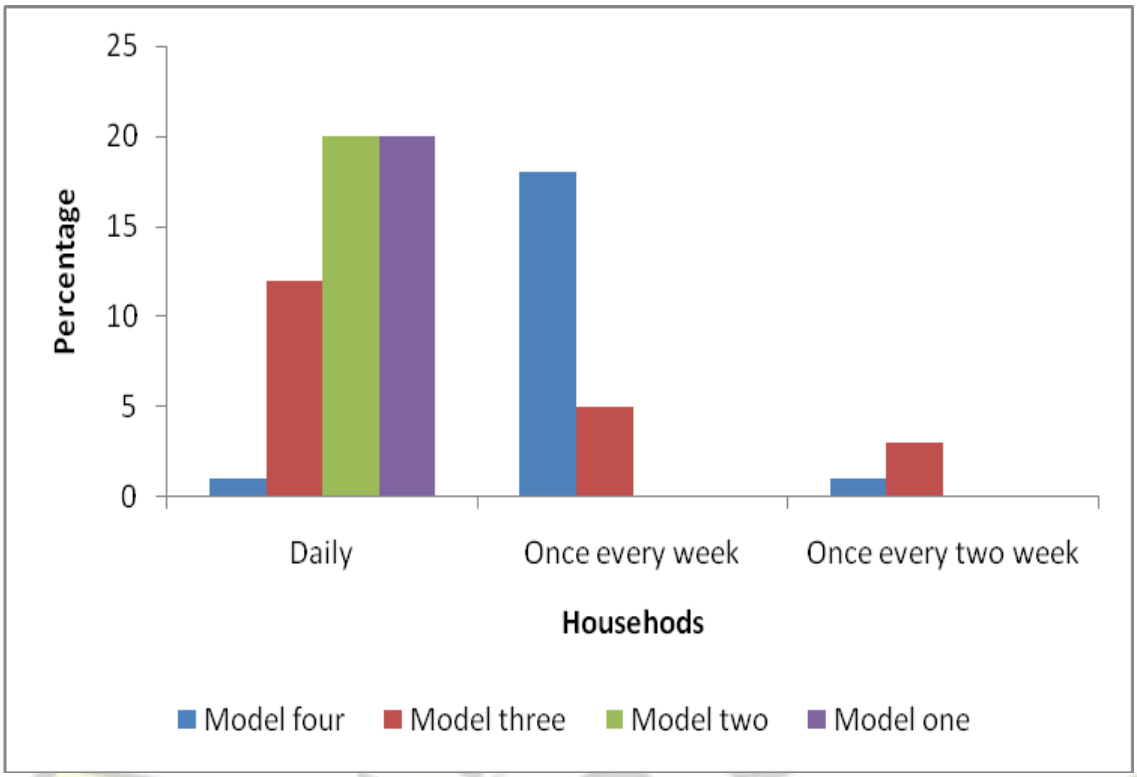


Figure 12: Frequency of waste collected

The results in figure 12 reveal that in model one and model two the waste is collected daily whiles in model three and model four, the waste is not collected daily. The waste is collected once every week or once every two weeks in model three and model four. This explains why the people are complaining of these systems of collection and need some modification to enhance the collection.

Some of these complains raised by people living close to the collection points and those using the waste bins as collection points in their homes include:

1. breeding of mosquitoes,
2. littering of the surrounding by children, rag pickers and wind,

3. bad odour from the collection points as a result of degradation of food waste

Statistical T-test was conducted on the various models of waste collection, at 95% significance level of confidence. It revealed that there was no significant difference between model three and four, two and three and one and three in collecting the waste but there were significant difference between model one and four, and model two and four (Appendix E). From field observation the waste collectors in model one would be difficult to monitor and controlled since their activities are not uniform but in model two the activities of the collectors can easily monitored and controlled since they are in an organized in institution. Therefore the best mode of waste collection was model two since it also has a local content of collecting the waste daily and early in the mornings as compare to all the other models.

4.14.2 Households satisfaction of the waste collection systems

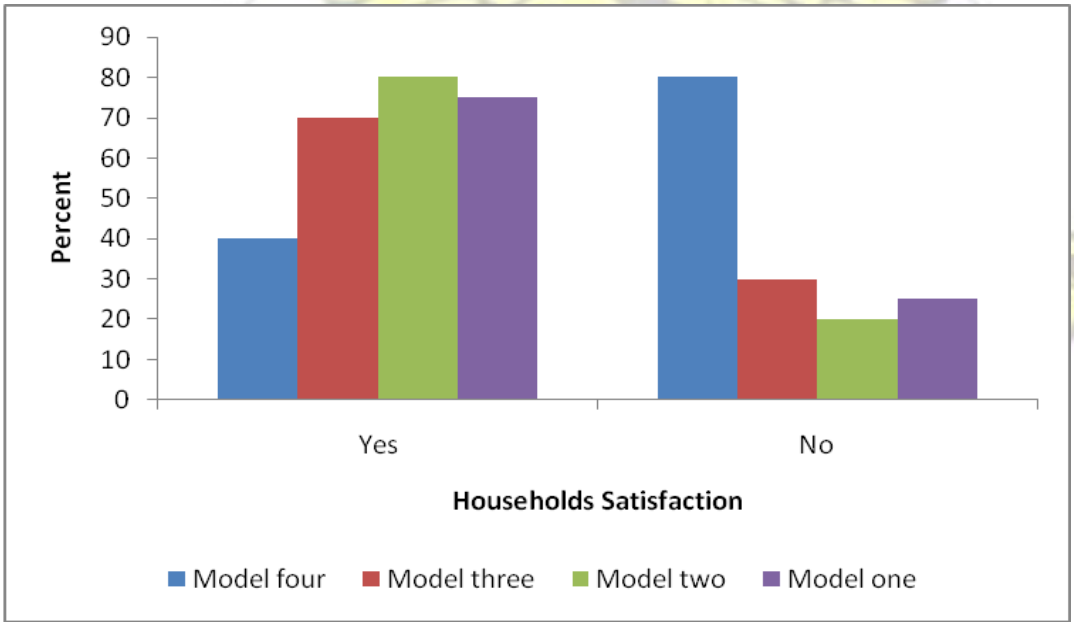


Figure 13: Satisfaction with the collection system.

Figure 13 indicates that about 80% of the respondents in the model two are satisfied with the waste collection system while 20% are not satisfied, about 75% of the respondents in model one responded positively in satisfaction of the waste collection system whiles 25% responded negatively; 70% of the respondents in model three responded positively in satisfaction of the collection system whiles 30% responded negatively and 35% of the respondents in model four responded positively in satisfaction of the waste collection system whiles 70% responded negatively.

4.15 Payment for waste collection and disposal

Tables 15 and 16 compare the responses of households in paying for waste collection and or disposing/dumping of waste in the various waste collection models. Table 15 indicates that in all the four models, respondents pay for disposing of their waste but in model one and model three about 5% of the respondents answered negatively. Most of them indicated that they managed their own waste at their homes by burning them in pits. They also added that they opted to manage their own waste because the companies do not pick up the waste on time. The results in table 16 also reveal that in model one, respondents pay a minimum of GH 4 cedis and maximum of GH 8 cedis per month; in model two, residents pay a minimum of 10 pesewes and maximum of GH 6 cedis a month; in model three, residents pay a minimum of 10 pesewas and maximum of 50 pesewas a day and in model four a minimum of 1 GH cedi and maximum of 20 GH cedis per month. Averagely, the companies charge between 3 and 4 GH cedis per month for collecting and disposing of the waste.

Table 15: Do you pay money for dumping/disposing off your waste

Options	Model One	Model Two	Model Three	Model Four
Yes	95	100	94.4	100
No	5	-	5.6	-

Mean	1.0500	1.0000	1.0556	1.0000
Std. Deviation	.22361	.00000	.23570	.00000

Source: Authors Field survey, November, 2009

Table 16: Amount of money paid per month for du mping waste

	Minimum	Maximum	Mean	Std. Deviation
Model One	4.00	8.00	4.2105	.91766
Model two	.01	6.00	3.4471	1.62293
Model Three	.10	.50	.1200	.08944
Model four	1.00	20.00	2.9000	5.84808

Source: Authors Field survey, November, 2009

4.16 Waste collection constraints

The private waste collection companies enumerated the following reasons as being the main constraints hindering waste collection in the metropolises:

1. Late payment by KMA to waste contractors,
2. Frequent breakdown of compaction trucks at the landfill site,
3. Inadequate supply of waste collection containers at the central collection points by KMA,
4. Lack of adequate capital to purchase waste bins for all households,
5. Inadequate waste collection vehicles for the collection of waste,
6. Frequent fuel shortage,
7. Traffic congestion,
8. Poor road network system,
9. Lack of technical expertise in the management of the landfill,

10. Behaviors of beneficiaries to waste collectors as second class citizens (Attitudinal change).

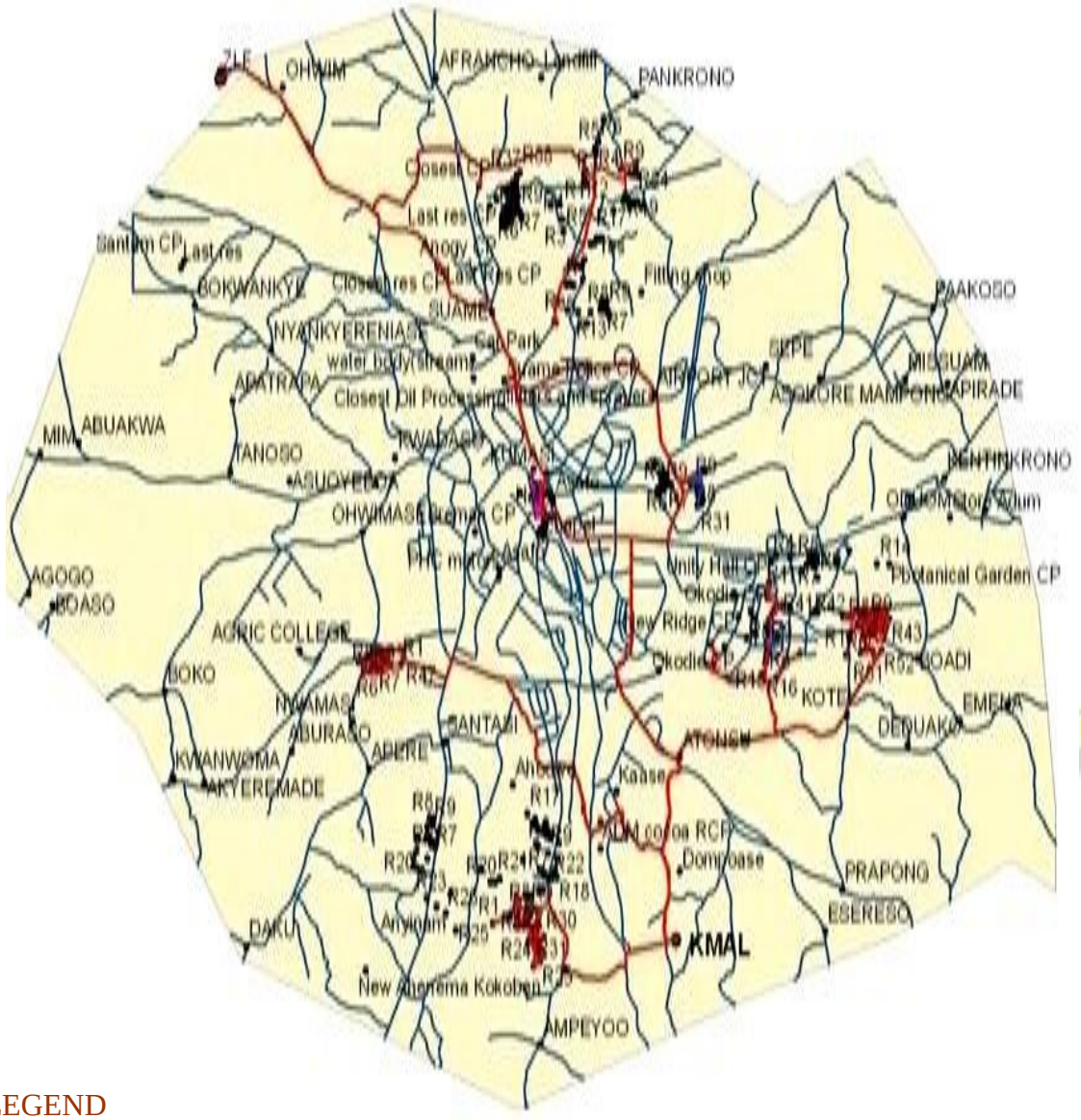
4.17 Recommendations to improve waste collection systems in the Kumasi Metropolitan Area

All the private waste collection companies recommend that, for efficient waste collection, there must be:

1. improved road network in the city,
2. intensive education on waste collection,
3. regular payment of waste contractors,
4. efforts by KMA to assist waste contractors to raise letters of credit to acquire logistics materials from their trading partners abroad,
5. waste collection everyday,
6. capacity building for the workers and staff of the private waste companies in waste management.

4.18 Results from the mapping of the four waste logistics models

The Northern and Eastern coordinates of the waste logistics points in the Kumasi metropolitan area were collected using GPS. The points are presented in appendix C. The points include all the Northern and the Eastern latitudes for waste collection and the disposal sites in the ten sub metros. The time used in the collection of waste at the central collection points, transporting the waste and disposing off the waste using the four different waste logistical collection models in the metropolis. The distances from the collection points to disposal sites were taken and presented in table 17. The results of the points are presented in the Kumasi map (figure 14)



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Routing from Collection Point to Landfill site

Road network

Collection Point

Land fill site

Figure 14: Waste Logistics Map of Kumasi Metropolitan area

The distances vary from one collection point to disposal sites and the farther the submetro from the disposal sites the farther the collection point to the disposal site. The study revealed that the private waste companies have collection schedules but they do not have route schedules for the vehicles to use from the collection points to the disposal site. The companies depend on the driver's judgments to decide which route the driver

prefers to use. The drivers said that they could transport the waste to any of the two disposal sites. The drivers cited two main factors that affect their decision to transport the waste to either of the two landfill sites. These are vehicular traffic and queuing at the landfill site. The drivers added that distances from the collection point to the landfill was not a factor even though some of the landfills were closer to some sub-metros than others. Some environmental practices were adopted by some of the collection companies. The drivers and the collectors of some of the open trucks used nets to spread on top of the garbage to prevent it from dropping on the road whiles it was being transported to the disposal site. Figure 14 shows some collection points, the routes and the disposal sites in the Kumasi metropolitan area. The distances from collection points to disposal sites are represented in Table 17.

Table 17: Distances from collection points to disposal sites

Sub metro	KMA Landfill	Zoomlion Landfill
Oforikrom	7.1 km	14.8 km
Subin	12	18
Asawasi	10.2 km	21.2 km
Nhyiaso	8.9 km	
Asokwa	3.6 km	18 km
Suame	15km	12.5km
Tafo	5.5 km	12.1 km
Kwadaso	13.5	8.7km

Source: Authors field data, August, 2009

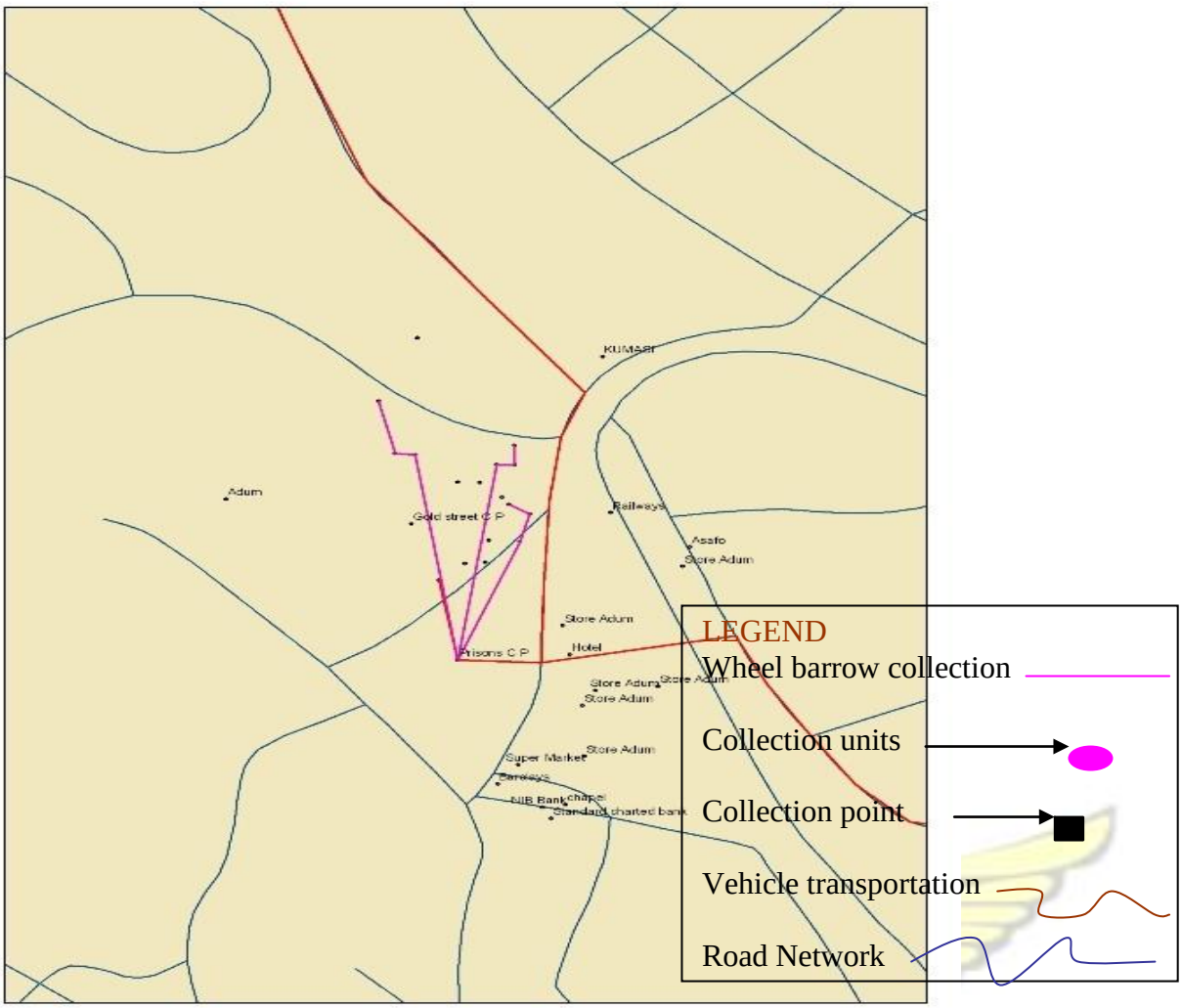


Figure 15: Adum waste collection and disposal system-central business town of Kumasi (Model one)

Figures 15 indicates how waste is collected from market stores, small shops, lorry parks and restaurants or chop bars using wheel barrows to the central collection points before it is transported to the disposal site using open trucks called skip loaders. The study also reveals that it takes an average of 5 minutes to collect waste from one collection unit and between 15 and 20 minutes to transport it to the central collection point. It takes an average of 30 minutes to lift the central container at central collection point and a minimum of 1hour 30minutes if there is no traffic on the road. It takes an average of 15 to 20 minutes to landfill the waste at the disposal site if there are no queues.

Collection starts at 8am and ends at about 4 pm. The driver collects and disposes off the waste five or six times a day depending on the traffic situation in a particular day.

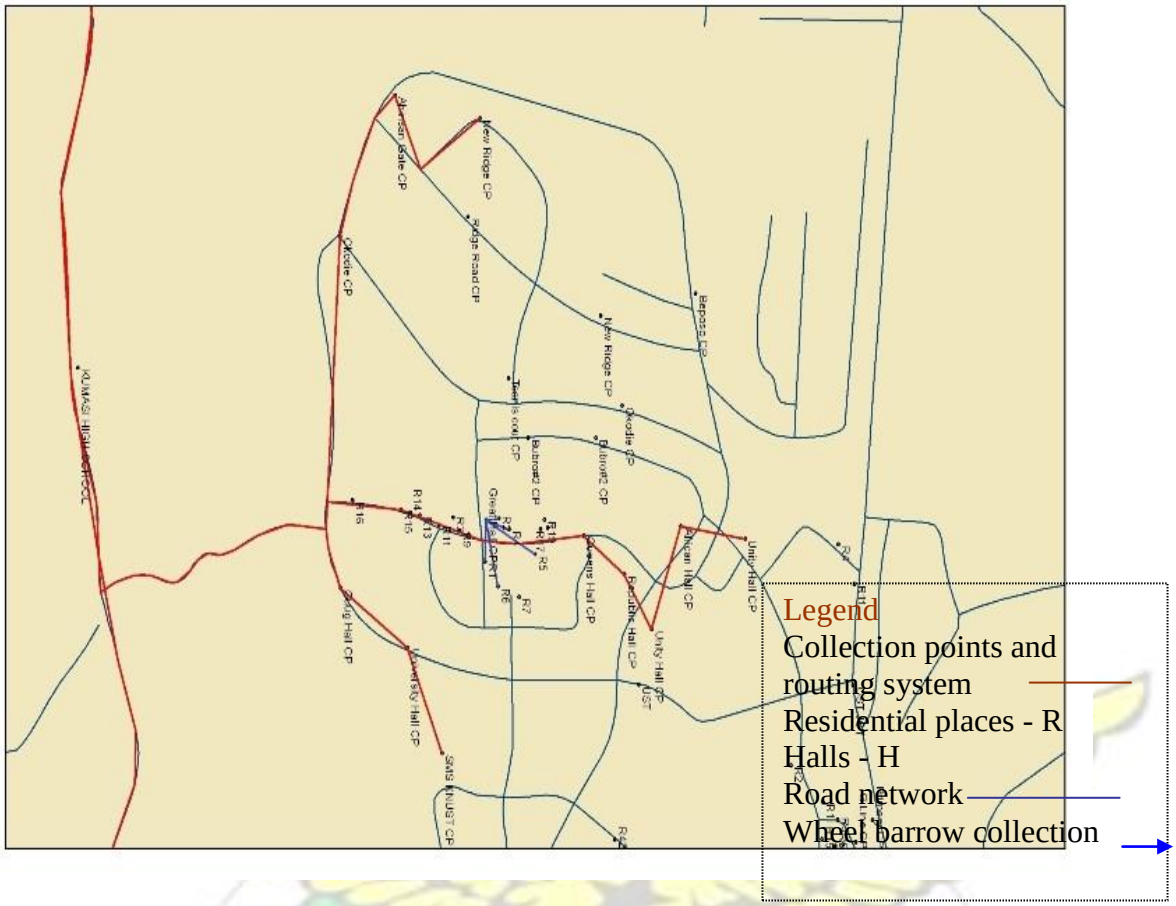


Figure 16: KNUST waste collection and disposal system - model two

Figure 16 represents the KNUST waste collection and disposal system. The university has employed waste collectors to collect waste from the residences and the university halls. The collection is done early in the mornings at 4am. The houses are zoned and each zone has one central collection point. The collectors use wheel barrows to collect the waste from the houses to the central collection point. The compaction trucks are provided by the university that moves from one collection point to another to collect the waste and transport it to the disposal site. It takes a minimum of 2 hours to gather all the waste from one zone to the collection point. The vehicle takes 3 - 4 hours to collect waste from one collection point this is because the workers used trowels, head pans, baskets, and hand fork to lift the waste into the vehicle. Also it takes an average of 2

hours for the vehicle to transport the waste to the landfill site. The vehicle collects the waste from the collection point to the disposal site twice or thrice a day. The waste collectors activity is usually affected by the difficulty involved in accessing fuel for the vehicles.

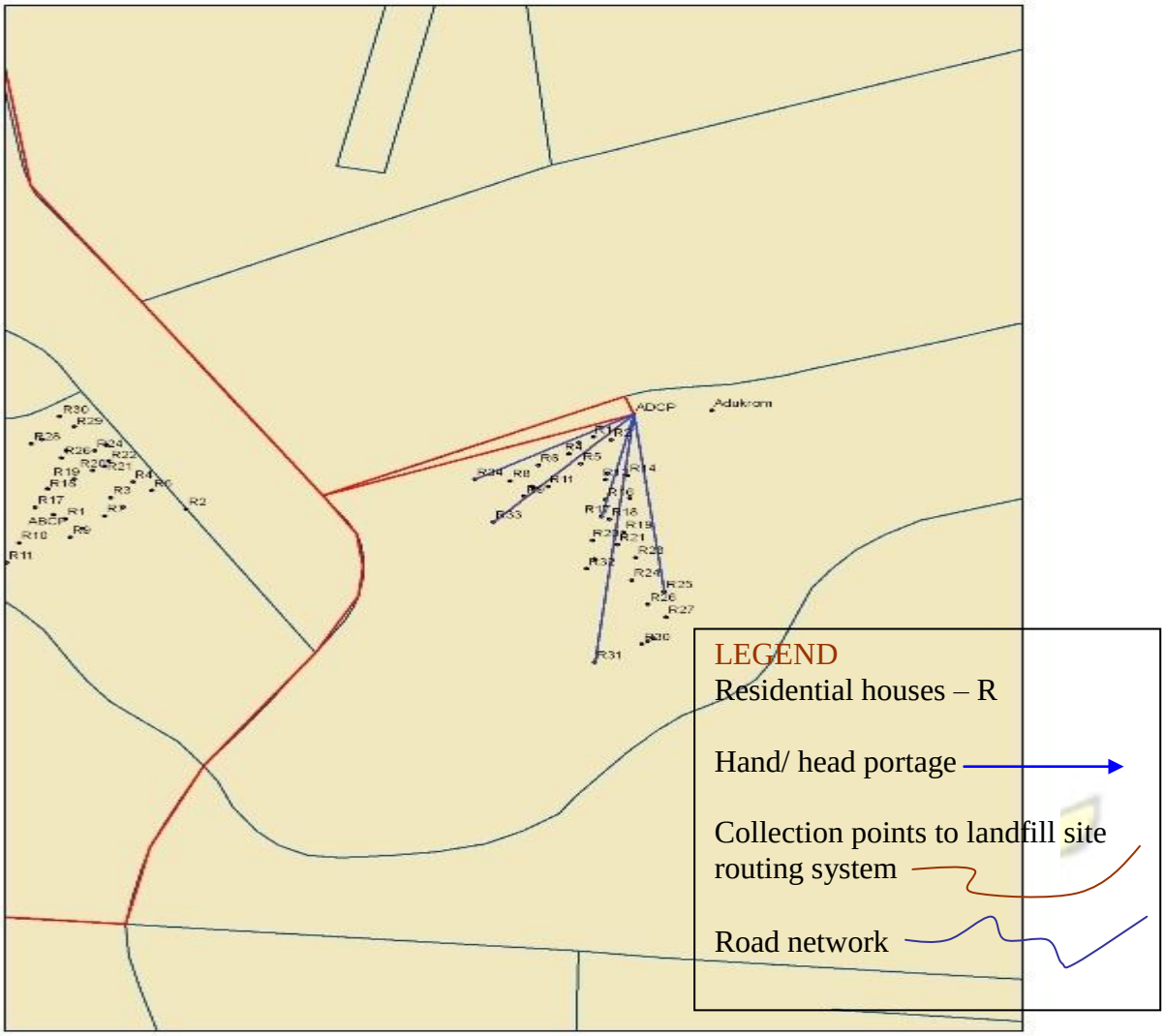
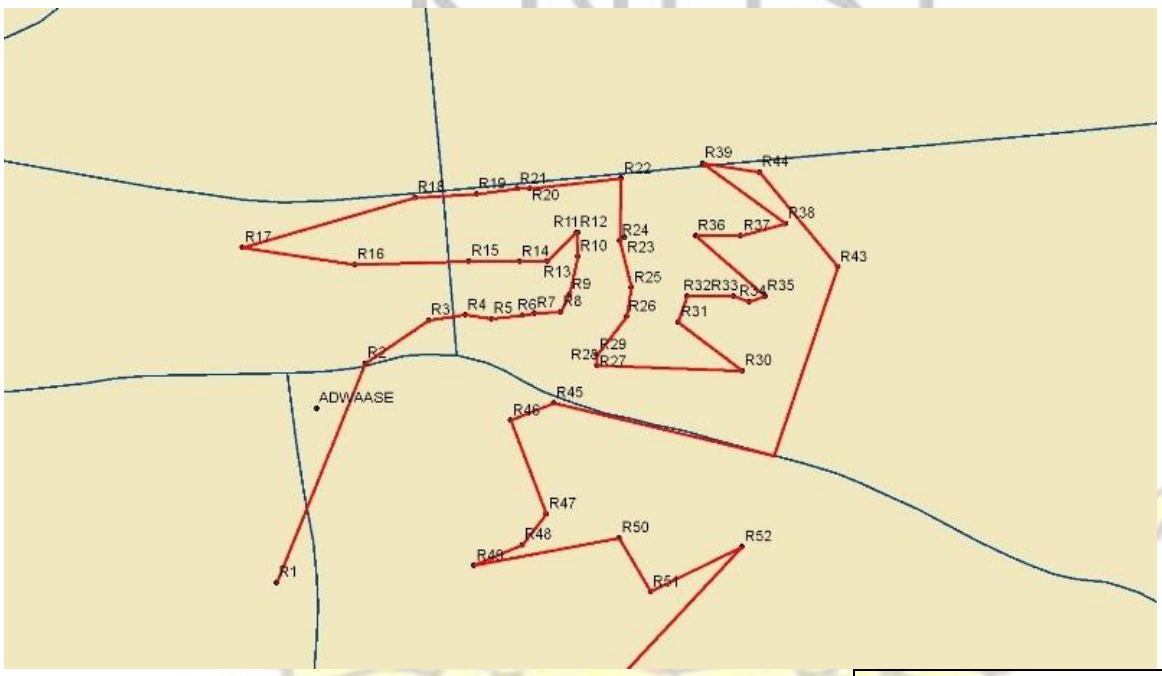


Figure 17: Communal waste collection system – model three

Figure 17 represents the central waste collection and disposal system in the Kumasi metropolis. It is mostly used in areas where the house to house collection was not be implemented, mostly in the slum and low income areas where the roads are not easily accessible due to the housing arrangements. A container is placed at a point for about 30 to 50 houses around and near that container to gather or dispose off their waste for collection and disposal. Depending on the population density of the particular area the container can be filled twice or thrice a day. It takes an average of 20 minutes for the skip trucks to prepare and lift the waste at the collection points to the disposal site.

The study also revealed that the vehicles used an average of 2 hours to and from the disposal sites and an average of 15 minutes to landfill the waste at the disposal site when there are no queues at the landfill site. The study also showed that the skip trucks can collect the waste five or six times a day from the collection points to the disposal site.



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Residential houses – R

Collection points and routing system

Road network

Figure 18: House to House waste collection system – model four

The study reveals in figure 18 that this system of waste collection is practised in high residential areas. Only vehicles are used in this system of collection. Households and institutions are provided with waste bins of 120 or 240 litres capacities. The households keep their waste in these bins for an average of one week before it is collected by the

collection company. It takes an average of 3-4 minutes for the collectors to empty a household collection container before the vehicle moves to the next house. The study revealed that it takes an average of 5 hours for the vehicle to collect waste from sixty to hundred houses before the vehicle is full and an average of one and half hour to dispose it off at the landfill. The compaction trucks that are used in this model of waste collection and disposal can at least collect and dispose off waste twice every day.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSIONS

The study has presented the results of the findings from the field survey conducted in November 2009 and the conclusions were based on the four key theoretical models that were used for the thesis namely:

1. Household waste generators are not aware of the amount of waste they produce everyday and even though the generation quantities are increasing everyday, the waste management department and the private waste collection companies are financially constrained to provide adequate logistics to collect and dispose off the waste. Households are not educated and informed on the need to change their attitudes towards waste generation and collection.
2. Majority of the waste generators are paying for the services offered by the private waste collection companies and the waste management department. The generators are willing to pay more if better services are provided.
3. Both the waste management department and private waste companies are aware of the alternative uses of waste but all the waste collected in the city are landfilled and none is recycled or put into other uses. Even though majority of the waste generators are willing to source separate their waste, there are no waste recycling plants, energy recovery plants and nutrient recovery plants in the metropolis except one pilot compost plant which is not in use.
4. The private waste contractors used open trucks, compaction trucks and a crew of three to four men to pass the trash into the trucks. In Kumasi where labour

is cheap, this has proved to be a success in the middle and high-income areas of Kumasi.

5. The model two waste collection system which is being implemented by KNUST community is the best of all the four waste collection models. The households are satisfied with the collection system. This system of collection has local content of collecting the waste everyday and early in the mornings even before the residents wake up. This system of collection is an improvement of the communal waste collection system of model three.
6. Households under models three and four are not satisfied with the waste collection systems that are currently used to collect and dispose off waste in the metropolitan area. The collection is not regular and the needed logistics are not provided to the households by the authorities.
7. The waste management department and the private waste collection companies are encouraging the house-to-house collection system but this system of collection as compared to the other three models of collection is expensive even though it is easier to recover cost of collection than in the other three models.

5.2 RECOMMENDATIONS

To begin with, it would be very interesting to conduct a research into the prospects of recycling of waste in Kumasi. This is to find out the viability of encouraging investment into the recycling business in Kumasi. Also, composting at home could be a way forward since a large portion of the solid waste emanating from the homes is degradable. It can be used for compound gardening and help cut down on the waste being sent to the landfill site from households. It will also reduce the burden of cash payments to waste collection companies.

Secondly, KMA and its development partners should adopt model two – the KNUST system of waste collection and disposal and conduct research to improve activities at its collection points to enhance waste separation. New investment drive must be injected into the waste sector by way of educating people about the business opportunities available in the sector and also making it attractive by providing the needed infrastructure and tax holiday for investment in the recycling and composting business. The households also need to know exactly what they should do to improve upon the services provided by the private contractors. There must be a form of platform whereby the two parties meet to discuss pertinent issues.

KMA and its development partners should promote waste disposal education in communities, workplaces and schools as well as research into approaches for better waste collection and disposal to help change peoples attitudes. Changing people's attitude to waste collection and disposal should also be premised on the provision of more waste collection and disposal logistics and effective waste collection systems in the city that can be easily reached to satisfy all households.

Finally KMA must collaborate with the Ministry of Food and Agriculture and large scale farmers to provide adequate waste logistics for effective recycling of household waste in the Kumasi Metropolis. This could reduce farmers burden of purchasing inorganic fertilizers and also protecting the environment from toxic substances and leaches from landfill sites. This can be achieved effectively by conducting research on waste separation at source and the residents must be well informed to make such an exercise efficient and long lasting. Composting and/or biogas plants would be good options for handling household waste.

REFERENCES

Aziz, H., (2004). Improving the livelihood of child waste pickers: experiences with the 'Zabbaleen' in Cairo, Egypt. An evaluative field study. *WASTE*, Gouda Netherlands.

Bach, H., A. Mild, M. Natter, and A. Weber, (2004). Combining socio-demographic and logistic factors to explain the generation and collection of waste paper, Resources, *Conservation and Recycling* 41: 65-73.

Bassis, Luke, (2009). Waste disposal. Scribd achieves. Available at http://www.scribd.com/doc/37760189/Waste-Disposal. Accessed on the (12/4/2011).

Boadi, Kwasi, O. and Kuitunen, Markku, (2003). Municipal solid waste management in Accra metropolitan area, Ghana. *The Environmentalist*, Volume 23. Number 3. Pp211-218. Available at http://www.springerlink.com/content/jp5q463u51877681.

Bogner, J., M. Abdelrafie, Ahmed, C. Diaz, A. Faaij, Q. Gao, S. Hashimoto, K. Mareckova, R. Pipatti, T. Zhang,(2007). *Waste Management, In Climate Change: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Botkin. B. D. and Keller, A. E., (2003). *Environmental science: Earth as a living planet*. John Wiley and Sons. Inc. USA. Fourth edition.

Bowersox, D. J., Closs, D. J., Cooper, M. B., (2002). *Supply Chain logistics management.* McGraw – Hill. USA.

Browne, Micheal and Allen, Julian, (2007). Logistics and waste sector- London case study. Transport studies group, University of Wetmaster. A paper presented at the logistics Research Network Conference. 5-7 September 2007. University of Hall.

Charles. Thrift, (2007). Sanitation Policy in Ghana: Key Factors and the Potential for Ecological Sanitation Soltions. *EcoSanRes Programme*, Stockholm Environmetal Institute, SEI Communication. Skockholm – Sweden. Also available at www.ecosanres.org. Accessed on 12/6/2009.

Definition of waste generation extracted available at BusinessDirectory.com. (3/1/2009)

Dias, Sonia Maria, (2000), Integrating Waste Pickers for Sustainable Recycling. Paper delivered at the Manila Meeting of the Collaborative Working Group (CWG) on Planning for Sustainable and Integrated Solid Waste Management, Manila.

Eerd, M. van, (1996). The occupational health aspects of waste collection and recycling: a survey of the literature. *UWEP Working Document* 4, Part I. WASTE, Gouda, The Netherlands.

Frazelle, Edward H. (2002). *Supply Chain Strategy: The Logistics of Supply Chain Management. New* York. McGraw-Hill.

Generation, Recycling, and Disposal in the United States Facts and Figures for (2006). Washington, DC 20460, Available at www.epa.gov/osw and accessed on (14/3/2010).

Ghana Statistical Service, (2000). Ghana living Standard Survey report of round 4. October, 2000. Ghana. Accessed on the 3/7/2009.

Hari, D., Sharma, S. and Lewis, P., (1994). *Waste Containment System, Waste Stabilization, and Landfills Design and Evaluation*. Canada. John Willy and Sons, Inc.. Hong Kong.. Also available at www.ilsr.oug. Accessed on 2/6/2009.

Isaac, A. T. and Enerst, M., (2004). A look at urban waste disposal problems in Accra, Ghana. A Masters thesis presented at Roskilde University.

Johansson, Ola, M., (2006). The effect of dynamic scheduling and routing in a solid waste management system: SciVerse –ScienceDirect. *Waste Management*. Volume 26, Issue 8 Pages 875-885.

Kaseva, M. E. and Mbuligwe, S. E., (2003). Appraisal of Solid Waste Collection following Private Sector Involvement in Dar es Salaam City. Tanzania. *Habitat International.*

Kelly, L., Richard, A. and Neil, S.,(2002). Zero waste: Replacing Waste Management with Discards Management in the Homg Kong Special Administration Region. Institute for Local Self – Reliance. Washington, DC 20009, for Greenpeace, China –

Kerale Envis Centre, (2009). *Waste generation*. The kerale state council for science and technology and environment. Thiruvanantharam.

Kitbuah, E., Asase, M., Yusif, S., Mensah. Y., Fischer, K., (2009). Comparative analysis of households waste in the cities of Stuttgart and Kumasi – options for recycling and treatment in Kumasi.

KMA –WMD, (2008). Waste Management Department Report. Available at www.kma.gov.gh//kumasimtro/page.com. cited on (1/7/2009)

Lakshumi, A. P. P., Ramiya, A. M. and Ssthya, R. (2006). Optimal Route Analysis For Solid Waste Disposal Using Geographical Information System. GIS Development. http://www.gisdevelopment.net/proceedings/mapindia/2006/student%20oral/mi06stu_113.htm Accessed 19th April, 2011

Lave, L., Hendrickson, C., Conway-Schempf, N., McMichael, F., (1999), Municipal solid waste recycling issues. *Journal of environmental Engineering*, pp. 944-949

Ljungberg, D., Gebresenbet, G. and Aradom, S. (2007). Logistics Chain of Animal and Abattoir Operations. Uppsala, Sweden. Biosystem Engineering Jounal: AP- Animal production Technology. ELSEVIER. Also available at www.sciencedirect.com

Majani, B., (2000). Institutionalising Environmental Planning and Management: The Economics of Solid Waste Management in Tanzania. SPRING Research Series no 28. Dortmund, Germany.

Mayor of London, (2003). *Municipal waste management strategy – Rethinking Rubbish on London*. Published by Greater London Authority.

Mensa, Anthony, and Larbi, Eugene, (2005). *Solid waste disposal in Ghana*. WELLFACT sheet – Regional Annex in Developing Countries. WELL – Resource Centre Network. Available at http://www.lboro.ac.uk/well/resources/fact-sheets/factsheets-htm/RSA%20Solid%20waste.htm . Accessed on (12/4/2020).

Mizpah, A., Enerst, K. Y., Moses, M., Jay, S., Samuel, A.,(2009). Comparism of municipal solid waste management system in Canada and Ghana: A case study of the cities London, Ontario and Kumasi Ghana. Waste Management 29: 2779–2786 available at www.elsevier.com/weste/wesman .

Peter, Appiah, Obeng, Emmanuel, A. Donkor, Anthony Mensah, (2009) "Assessment of institutional structures for solid waste management in Kumasi", *Management of Environmental Quality: An International Journal*, Vol. 20 Iss: 2, pp.106 - 120

Poku, Omane, (2009). *Waste disposal management in the pere-urban areas of kumasi*. DFID funded project: R7330, Kumasi, Ghana. Retrieved from www.dfid.com. (11/11/2009)

Republic of Ghana, (1991). Comprehensive Development Framework Decentralisation. By Ministry of Local Government and Rural Development.

Roel, G. Eddy, V. V. and Thierry, V. (2010). Assessing characteristics of waste logistics from an innovation perspective. An article for ETC, Department of Transport and Regional Economics Faculty of Applied Economics University of Antwerp

Sampson, G., (2003). *Improving Waste Collection Logistics*. Article from The Edge Vision 21 Transport Magazine.

Samuel, Sarpong, (2009). Mayor of Kumasi Metropolitan Assembly. Press released by the Mayor of KMA. 23rd July, 2009, Edition of Daily Graphic.

Scheinberg, Anne, Justine A. and Arnold van de K., (2006) Waste pickers: poor victims or waste management professionals. Paper No. 56 presented at the CWG- WASH Workshop, 1-5 February, 2006. Kolkoba, India.

Taylor, D. C., (1999). Managing resources to collect municipal resources to collect municipal solid waste. Illustrative East Asian case study studies. Published by waste management and research SAGE. http//wmr.sagepub.com (12/7/2010).
Tchobanglous, G., Theisen, H., Eliassen, R., (1993). *Integrated Solid Waste Management – Engineering Principles and Management*. Mc Graw – Hill publishing company. USA.

Tettenborn , F., Kaneva, I., Grunauuer , J., Winker, M., and Otterpohl, R., (2007). Transport and logisticts basics in the context of new sanaitation concepts. Paper presented at the 2nd SWITCH Scientific Meeting Dan Panorama Hotel. 25-29 November 2007, Tel-Aviv, Israel

Thomas Kistner, (2005). Efficient waste management in focus of a logistics provider. Dautche post, DHL Solutions.

United States Environmental Protection Agency, (2007). Municipal Solid Waste

Zero Waste New Zealand Trust, (2000). Zero Waste New Zealand: Profile of a National Campaign September, 2000. New Zealand, Available at www.zerowastenz.com Accessed on the 12/6/2009.

APPENDIX A
WASTE LOGISTICS SURVEY QUESTIONNAIRE

Improving Waste Logistics in the Kumasi Metropolitan Area

Questionnaires for private waste collection companies

Questionnaire Number.....

Interviewer Name.....

Date of Interview (DD/MM/YY)...../...../200.....

1) Name of private waste collation company (NPWCC)……

2) Coverage area (Name of Sub-metro Covered……

3) Amount of waste collected daily / month……

4) Methods of collection from different sources

- ☐ House to House collection
- ☐ Communal collection using transfer stations
- ☐ Others (Specify)……..

5) How many houses does the compactor vehicle go to before it is full?

- ☐ 50-100
- ☐ 100-150
- ☐ 150-200

Above 250 houses

6) How many houses contribute waste to the central containers?

- ☐ 50-100
- ☐ 100-150
- ☐ 150-200
- ☐ Above 250 houses

7) How many vehicles do you use in collecting waste in the catchments area….

8) a. Are there other forms of transport used for the collection of waste?

☐ Yes ☐ No

b. If yes, (Specify) them……

9) Are they approved routes by KMA to be used by these vehicles?

☐ Yes ☐ No

10)Indicate the specific routes the vehicles use from the collection points to the final disposal site

……

……

……

……

11) a. Do you provide Households with waste collection materials?

- ☐ Yes
- ☐ NO

b. If yes, which ones? ……..

c. How many? ……

12) Do you encourage source separating of waste at the household level?

- ☐ Yes
- ☐ No

13) Would you be willing to give any incentives for source separating of waste?

- ☐ Yes
- ☐ No

14) Are Households trained on how to use these materials?

- ☐ Yes
- ☐ No

15) How were the transfer's stations designated?

- ☐ KMA
- ☐ EPA
- ☐ Private Waste Companies
- ☐ Others (Specify)

16) How many of the transfer stations are within your sub metro catchments area?

17) What activities are undertaken at the transfer stations?

- ☐ Loading
- ☐ Raking to uniform or spread the waste in the container
- ☐ Collection of fees
- ☐ Others (Specify)……..

18) Are the collection containers protected from the weather?

- ☐ Yes
- ☐ No

19) From the transfer stations where do you send the waste?

- ☐ Recycling centre
- ☐ Energy/Compost recovery centre
- ☐ Incinerations Plants
- ☐ Landfill centre

20) Does your company have a recycling unit?

- ☐ Yes
- ☐ No

21) Does your company have Energy/Nutrient recovery centre?

- ☐ Yes
- ☐ No

22) a. Does your company own a Landfill?

- ☐ Yes
- ☐ No

b. If No where do you dump your waste? KMA landfill sites

- ☐ Others (Specify them)……..

23) a. ☐ Do you have suggestions on how you can improve upon the collection system?

- ☐ Yes
- ☐ No

b. If yes, (specify them)……

24) a. Are there ways we can re-use the waste?

- ☐ Yes
- ☐ No

b. If yes, how? ……

c. If no, why? ……

25) What times of the day do you collect the waste?

- ☐ Mornings
- ☐ Afternoons
- ☐ Evenings
- ☐ Others (Specify)……..

26)How often do you collect the waste from the Houses and transfer stations?

- ☐ Daily
- ☐ Weekly
- ☐ Others (Specify)……..

27) How far is the collection point from the disposal end?.....km 28) How many times can a vehicle collect waste to the landfill in a day?

- ☐ Once
- ☐ Twice
- ☐ Thrice
- ☐ Others (Specify)……

29) How much do you spend every month in collecting the

- ☐ waste?…cedis 30) What account for the cost? Fuel
- ☐ Spare parts
- ☐ Servicing of vehicles
- ☐ Others (Specify them)……..

31) a. Do you pay fees before disposing of waste at the land fill site?

- ☐ Yes
- ☐ No

b. If yes, how much? ……..

c. If no, why? ……

32) What activities are undertaken at the disposal points?

- ☐ Unloading
- ☐ Weighing
- ☐ Spreading
- ☐ Others (Specify)……

33) a. Are there queues of vehicles at the landfill site?

- ☐ Yes
- ☐ No

b. If yes, what is causing it?

☐ Spreading and Compaction

☐ Weighing

☐ Unloading

☐ Others (Specify)……

34) What are the main constraints you think on waste collection?

.....

.....

.....

.....

.....

.....

35) What are your recommendations to promote effective waste collection?

.....

.....

.....

.....

Thank you.

APENDIX B

WASTE LOGISTICS SURVEY QUESTIONNAIRE

Improving Waste Logistics in the Kumasi Metropolitan Area

Questionnaire Number.....

Interviewer Name.....

Age of Respondent (Specify in years)……years

Gender of Respondent ☐ Male ☐ Female

Date of Interview (DD/MM/YY)...../...../200.....

Name of the Area.....

House Number.....

Educational level of Respondent

☐ Primary ☐ Junior High ☐ Tertiary ☐ Others (Specify).....

Marital status of respondent

☐ Married ☐ Single ☐ Divorced ☐ Others (Specify).....

INTRODUCTION

Please I am (interviewers name), a student of

.....who would like to spend 20 minutes of your time by asking you a few questions concerning waste collection and disposal. This is an academic exercise it is not to investigate the activities of any organisation or company.

1.House hold size ☐ 1 – 3 ☐ 4 – 6 ☐ above 7 ☐ 2.

a. Do you have waste a bin or container? ☐ Yes ☐ No

b. If yes, who supplied you with this waste bins?

- ☐ District assembly
- ☐ Waste companies
- ☐ Bought it
- ☐ Others (Specify)……

c. If no, how do you keep your waste?

- ☐ Jute sacks
- ☐ Old baskets
- ☐ Broken buckets
- ☐ Others (Specify)…….

3. Where do you keep your waste bins in the house? ☐ At the backyard

- ☐ At the gate
- ☐ At the yard
- ☐ At the kitchen
- ☐ Others (Specify)…….

4. a. Do you source separate your waste?

- ☐ Yes
- ☐ No

b. If yes, how do you separate them? ☐ Food waste

Non food waste

☐

☐ Others (specify)…….

c. If no, would you be willing to separate your waste?

☐ Yes

☐ No

5. Do you need any incentives to separate your waste?

☐ Yes

☐ No

6. a. Does someone come to your home to collect the waste? ☐ Yes (answer 4b and leave Q5-8)

☐ No (answer Q5-8 and leave 4b)

b. If yes who/which company does that? ……

7. How often do you dispose of your house hold waste?

☐ Once daily

☐ Once every week

☐ Others (Specify)……

8. Who carries the waste bins to the disposal sites (Bola)?

☐ Children

☐ Women

☐ Maid

☐ Others (Specify)……..

9. By what means does the person carry the waste to the Bola?

☐ Head or hand carrying

☐ Wheel barrow

☐ Tricycle

☐ Others …….

10. How far is the disposal site (Bola) from your home?

☐ 10 meters

☐ 30 meters

☐ 50 meters

☐ Above 50 meters

11. a. Do you pay money for dumping/ when your waste is collected from your home?

☐ Yes

☐ No

b. If yes, How much? ……

12. a. Have you received education on how to handle and dispose of your waste? Yes No. ☐

b. If ☐ yes (specify) what type of training?

☐ Safety keeping of waste bins to prevent breeding of mosquitoes and insects

☐ Hygienic way of keeping waste bins

☐ Others (specify)……..

13. Who is responsible for collecting your waste in your community?

☐ D A

☐ Zoom lion

☐ ABC waste group

☐ Others (specify)……

14. How often do they collect the waste?

☐ Daily

☐ Once every week

☐ Monthly

☐ Others (specify)

15. a. Are you satisfied with their collection service?

☐ Yes

☐ No

b. If yes, How? ……. …….

c. If no, why? .....

Thank you and GOD BLESS YOU

APPENDIX C

Waste logistic collection and disposal points for the subin sub metro

LOCATION	TYPE OF MODEL USED	CORDINATES	
Kejetia and Central Business Town	ONE	**NORTHINGS**	**EASTINGS**
Prisons C P	ONE	734038.178	673759.447
	ONE	734622.748	673659.444
Gold street C P	ONE	735036.079	673508.852
Start CP1	ONE	735550.1	673418.836
CP2	ONE	735933.125	673328.653
CP3	ONE	736396.379	673540.803
CP3	ONE	735539.883	673529.641
CP4	ONE	735338.057	673761.096
CP5	ONE	734753.424	673911.47
CP6 End	ONE	734904.33	674103.075
Prison CP	ONE	734038.178	673759.447
Start CP1	ONE	735105.798	674153.702
CP2	ONE	735468.784	673972.823
CP3	ONE	735337.904	673881.988
CP3 End	ONE	735636.003	661631.895
Prison CP	ONE	734038.178	673759.447
Start CP1	ONE	735609.729	674073.746
CP2	ONE	735468.657	674073.567
CP3	ONE	735176.474	674042.974
CP3	ONE	735226.908	674002.74
CP4	ONE	734914.623	673931.823
CP5	ONE	734743.488	673800.639
KMA LF	ONE	709115.645	684559.526

Waste logistic collection and disposal points for the subin sub metro

LOCATION	TYPE OF MODEL USED	CORDINATES	
Adum	FOUR	**NORTHINGS**	**EASTINGS**
chapel	FOUR	732979.385	674352.501

Standard charted bank			
	FOUR	732878.721	674271.778
NIB Bank	FOUR	732959.398	674221.507
Barclays	FOUR	733131.006	673979.936
Super Market	FOUR	733271.937	674090.934
Hotel	FOUR	734077.706	674374.039
Store Adum	FOUR	733704.784	674444.089
Store Adum	FOUR	733815.537	674514.75
Store Adum	FOUR	733331.938	674453.692
Store Adum	FOUR	733890.397	705060.377
Store Adum	FOUR	733845.334	674857.319
Store Adum	FOUR	734289.365	674334.009
Store Adum	FOUR	734721.831	674989.393
Railways	FOUR	735115.313	674596.988
Asafo	FOUR	734862.852	675029.868
Asafo	FOUR	731230.408	670934.994
Asafo	FOUR	730776.988	670914.264
PHC motors	FOUR	720916.18	675576.539
KMALF	FOUR	709115.645	684559.526

Waste logistic collection and disposal points for the suamy sub metro

LOCATION	TYPE OF MODEL USED	CORDINATES	
Breman	THREE	**NORTHINGS**	**EASTINGS**
Breman CP	THREE	733187.564	669154.314
Closest res. CP	THREE	751143.731	669449.606
Last res CP	THREE	750476.989	670748.226
ZLF	THREE	756702.479	649834.155
closest Res to landfill	THREE	757014.672	649965.55
Anogy	THREE		
Anogy CP	THREE	747076.942	666261.013
Closest res CP	THREE	746976.162	666270.954
Last Res CP	THREE	746743.75	666764.263
ZLF	THREE	756752.677	649965.179

Old suame	THREE		
Suame Police CP	THREE	741004.187	671350.515
Closest Oil Processing			
	THREE	741024.198	671461.355
fittters and sprayers	THREE	741004.2	671340.441
water body(stream)	THREE	741138.176	669033.65
ZLF	THREE	756702.479	649834.155
Same Trotro CP	THREE	742365.865	1262562.174
Closest residece	THREE	742446.485	1262562.01
ZLF	THREE	756702.479	649834.155

Waste logistic collection and disposal points for the Suamy sub metro

LOCATION	TYPE OF MODEL USED	CORDINATES	
Nkontwima	FOUR	**NORTHINGS**	**EASTINGS**
R1	FOUR	749780.961	671321.52
R2	FOUR	749579.598	671190.304
R3	FOUR	749700.387	671291.195
R4	FOUR	749861.197	671613.757
R5	FOUR	749891.284	671724.605
R6	FOUR	749911.282	671845.514
R7	FOUR	749971.651	671916.106
R8	FOUR	750021.956	671976.613
R9	FOUR	749599.491	671391.801
R10	FOUR	749378.078	671179.97
R11	FOUR	749216.528	671431.602
R12	FOUR	749276.43	671864.844
R13	FOUR	749166.483	671169.623
R14	FOUR	749236.837	671310.745
R15	FOUR	749055.224	671491.836
Brema Nkontwima	FOUR		
R1	FOUR	749528.63	671643.55
R2	FOUR	749568.794	671754.411
R3	FOUR	749608.88	671925.713
R4	FOUR	749669.275	671976.159
R5	FOUR	749689.273	672097.068
R6	FOUR	749749.642	672167.66
R7	FOUR	749789.806	672278.521
R8	FOUR	749819.893	672389.369
R9	FOUR	749799.611	672490.079
R10	FOUR	749728.971	672570.577

R23	FOUR	750546.329	671675.081
R24	FOUR	750758.119	671534.325
R25	FOUR	750919.449	671453.945
R26	FOUR	750949.627	671494.278
R27	FOUR	751070.403	671605.242
R28	FOUR	750949.12	671887.144
R29	FOUR	750717.164	672037.948
R30	FOUR	750545.654	672198.904
R31	FOUR	750646.175	672390.43
R32	FOUR	750847.953	672199.293
R33	FOUR	750999.141	672169.266
R34	FOUR	751150.238	672209.755
R35	FOUR	751331.902	671988.372
R36	FOUR	751331.604	672220.061
R37	FOUR	751684.233	672260.809
R38	FOUR	751845.135	672512.852
ZLF	FOUR	756702.479	649834.155
R11	FOUR	749487.081	672610.561
R12	FOUR	749950.863	672409.684
R13	FOUR	750041.63	672349.36
R14	FOUR	750253.304	672299.264
R15	FOUR	750293.713	672218.727
R16	FOUR	750404.737	672077.84
R17	FOUR	750364.561	671977.053
R18	FOUR	750264.093	671745.232
R19	FOUR	750223.799	671735.107
R20	FOUR	750193.673	671654.48
R21	FOUR	750113.229	671523.42
R22	FOUR	749982.532	671291.559

Waste logistic collection and disposal points for the Asokwa sub metro

LOCATION	TYPE OF MODEL USED	CORDINATES	
		NORTHINGS	EASTINGS
ADM cocoa RCP	THREE	716700.433	678593.895
ADM cocoa CSCP	THREE	718111.123	678615.784
Landfill	THREE	709115.645	684559.526

Waste logistic collection and disposal points for the Kwadaso sub metro

LOCATION	TYPE OF MODEL USED	CORDINATES

Agric Chema Kwadasu			
	FOUR	**NORTHINGS**	**EASTINGS**
R1	FOUR	726242.063	663513.454
R2	FOUR	726202.73	662777.93
R3	FOUR	726162.624	662626.752
R4	FOUR	726012.29	662011.979
R5	FOUR	725992.257	661921.278
R6	FOUR	725891.746	661729.72

R7	FOUR	725972.453	661659.302
R8	FOUR	725972.761	661427.578
R9	FOUR	725912.49	661286.448
R10	FOUR	725892.498	661165.521
R11	FOUR	725882.986	660742.359
R12	FOUR	726003.865	660772.746
R13	FOUR	726225.686	660672.292
R14	FOUR	726396.746	660853.87
R15	FOUR	726397.42	660350.123
R16	FOUR	726396.235	661236.718
R17	FOUR	726819.4	661277.582
R18	FOUR	726819.467	661227.208
R19	FOUR	726708.114	661609.907
R20	FOUR	726476.58	661438.324
R21	FOUR	726808.934	661569.742
R22	FOUR	726839.057	661650.381
R23	FOUR	726848.972	661771.293
R24	FOUR	726727.945	661851.732
R25	FOUR	726546.526	661881.715
R26	FOUR	726405.239	662042.727
R27	FOUR	726415.181	662143.489
R28	FOUR	726365.173	661861.324
R29	FOUR	726355.284	661720.262
R30	FOUR	726899.061	661993.008
R31	FOUR	726687.277	662123.701
R32	FOUR	726939.032	662244.935
R33	FOUR	726959.105	662305.411
R34	FOUR	726989.108	662476.724
R35	FOUR	726898.498	662416.155
R36	FOUR	726848.102	662426.163
R37	FOUR	726747.322	662436.104
R38	FOUR	726656.539	662506.508
R39	FOUR	726535.686	662455.973
R40	FOUR	726364.33	662496.045
R41	FOUR	726203.104	662495.831
R42	FOUR	727009.087	662607.725
R43	FOUR	727059.337	662708.541
R44	FOUR	727049.046	662869.726
R45	FOUR	727058.376	663433.933
R46	FOUR	726846.408	663705.676
R47	FOUR	726493.726	663705.21
KMALF	FOUR	709115.645	684559.526

Waste logistic collection and disposal points for the Oforikrom sub metro

LOCATION	TYPE OF MODEL USED	CORDINATES	
		NORTHINGS	EASTINGS
R1	FOUR	726754.979	697164.08

R2	FOUR	728034.107	697679.338
R3	FOUR	728285.597	698052.385
R4	FOUR	728315.588	698263.987
R5	FOUR	728295.265	698415.084
R6	FOUR	728315.213	698596.45
R7	FOUR	728325.21	698666.984
R8	FOUR	728335.117	698818.115
R9	FOUR	728435.824	698868.601
R10	FOUR	728657.45	698919.224
R11	FOUR	728798.531	698909.308
R12	FOUR	728798.52	698919.382
R13	FOUR	728627.424	698737.847
R14	FOUR	728627.606	698576.653
R15	FOUR	728627.935	698284.489
R16	FOUR	728608.533	697619.54
R17	FOUR	728710.04	696964.804
R18	FOUR	729001.116	697972.596
R19	FOUR	729020.871	698325.23
R20	FOUR	729050.749	698637.577
R21	FOUR	729050.828	698567.055
R22	FOUR	729110.607	699171.599
R23	FOUR	728767.985	699191.363
R24	FOUR	728747.866	699161.117
R25	FOUR	728475.723	699231.333
R26	FOUR	728304.457	699200.917
R27	FOUR	728022.509	699029.331
R28	FOUR	728022.509	699029.331
R29	FOUR	728082.968	699029.399
R30	FOUR	727991.331	699875.569
R31	FOUR	728273.889	699503.123
R32	FOUR	728424.979	699553.665
R33	FOUR	728424.674	699825.68
R34	FOUR	728394.344	699916.318
R35	FOUR	728424.471	700007.023
R36	FOUR	728777.598	699604.433
R37	FOUR	728777.305	699866.373
R38	FOUR	728847.547	700128.392
R39	FOUR	729200.764	699645.206

R40	FOUR	728994.411	695010.649
R41	FOUR	728984.438	694919.965
R42	FOUR	728934.426	694597.52
R43	FOUR	728595.298	700430.349
R44	FOUR	729150.009	699977.611
R45	FOUR	727801.11	698777.216
R46	FOUR	727700.629	698525.235
R47	FOUR	727156.263	698736.192
R48	FOUR	726975.045	698594.942
R49	FOUR	726854.446	698312.713
R50	FOUR	727014.717	699159.171
R51	FOUR	726702.144	699340.165
R52	FOUR	726963.534	699874.419
KMALF	FOUR	709115.645	684559.526

Waste logistic collection and disposal points for the Oforikrom sub metro

LOCATION	TYPE OF MODEL USED	CORDINATES	
		NORTHINGS	EASTINGS
SMS KNUST CP	TWO	726819.422	693678.288
Great Hall CP	TWO	727356.35	691200.521
Queens Hall CP	TWO	728545.187	691363.104
African Hall CP	TWO	729734.33	691263.745
G.Line CP	TWO	731876.732	694621.05
Primary CP	TWO	732078.529	694389.57
Pbotanical Garden CP	TWO	731457.008	700433.544
Hall Six CP	TWO	731622.779	696403.942
Swimming Pool CP	TWO	732145.575	697442.206
Unity Hall CP	TWO	730520.143	691395.632
Unity Hall CP	TWO	729380.374	692361.466
Republic Hall CP	TWO	729048.53	691776.752
University Hall CP	TWO	726397.514	692549.425
Guug Hall CP	TWO	725582.045	691923.841
Okodie CP	TWO	725576.35	688186.064
Bubro#2 CP	TWO	727871.276	690324.622
Bubro#2 CP	TWO	728697.548	690325.591
Teanis cout CP	TWO	727630.185	689689.631
Ridge Road CP	TWO	727138.458	687976.342
Ahinsan Gate CP	TWO	726243.182	686685.704
New Ridge CP	TWO	727280.774	686928.735
New Ridge CP	TWO	728759.535	689026.03
Beposo CP	TWO	729918.606	688795.682
Okodie CP	TWO	729020.398	689983.431
KMALF	TWO	709115.645	684559.526

Waste logistic collection and disposal points for the Oforikrom sub metro

LOCATION	TYPE OF MODEL USED	CORDINATES	
G. HALL	TWO	**NORTHINGS**	**EASTINGS**
R1	TWO	727345.757	691643.798
R2	TWO	727517.597	691180.56
R3	TWO	726953.326	691169.827
R4	TWO	727638.374	691301.598
R5	TWO	727960.516	691563.916
R6	TWO	727506.676	691905.928
R7	TWO	727758.459	692017.043
R8	TWO	727144.568	691351.396
R9	TWO	727033.773	691310.967
R10	TWO	726912.879	691290.677
R11	TWO	726781.932	691250.225
R12	TWO	726671.149	691199.722
R13	TWO	726550.29	691149.207
R14	TWO	726429.408	691118.842
R15	TWO	726318.602	691088.488
R16	TWO	725724.207	690987.046
R17	TWO	728021.292	691291.97
R18	TWO	728111.992	691282.001
R19	TWO	728071.792	691191.282

Waste logistic collection and disposal points for the Oforikrom sub metro

LOCATION	TYPE OF MODEL USED	CORDINATES	
G LINE	TWO	**NORTHINGS**	**EASTINGS**
R1	TWO	731474.161	694197.459
R2	TWO	731081.631	693804.1
R3	TWO	731655.328	694379.008
R4	TWO	731658.715	691457.409
R5	TWO	731624.774	694661.059
R6	TWO	731654.842	694802.136
R7	TWO	731715.115	694963.397
R8	TWO	731573.999	695003.533
R9	TWO	730777.946	695012.694
R10	TWO	731825.957	694963.524
R11	TWO	731859.752	691880.772
R12	TWO	731815.996	694862.768
R13	TWO	731715.486	694641.014
R14	TWO	731478.165	699536.94
R15	TWO	731463.632	694590.352

R16	TWO	731382.846	694741.376

Waste logistic collection and disposal points for the Tafo sub metro

Zongo church CP Closest Food store	THREE	744573.112	677872.89
&Tailoring	THREE	748099.924	677867.229
res	THREE	748190.26	678149.404
res	THREE	748411.756	678300.786
res	THREE	748411.441	678552.626
last res	THREE	748391.024	678764.146
ZLF	THREE	756702.479	649834.155

LOCATION	TYPE OF MODEL USED	CORDINATES	
New Tafo		**NORTHINGS**	**EASTINGS**
Moro Market CP	THREE	744072.577	675253.057
Yam market	THREE	744092.895	675122.122
Res	THREE	746317.078	677300.868
Res	THREE	745995.551	676565.08
Last res	THREE	744544.043	676946.06
Fitting shop	THREE	745646.558	681702.265
Landfill	THREE	756820.913	674130.956
Santam CP	THREE	747244.272	647110.928
Closest res	THREE	747304.456	677402.844
res	THREE	746952.079	677160.633
res	THREE	746952.155	677100.191
res	THREE	747032.97	676939.113
res	THREE	746992.98	676687.22
Last res	THREE	746871.748	646888.772
ZLF	THREE	758788.452	680056.416

Waste logistic collection and disposal points for the Tafo sub metro

LOCATION	TYPE OF MODEL USED	CORDINATES	
		NORTHINGS	EASTINGS
Ahinshiasu CP	FOUR	746056.328	676313.313
R1	FOUR	746036.53	676031.222
Private School	FOUR	746036.251	676252.845
Private school	FOUR	744696.256	676100.049
Assembly of God	FOUR	744692.836	678830.054
R2	FOUR	744975.156	678689.372
R3	FOUR	745227.007	678740.055
R4	FOUR	745156.271	678901.148
R5	FOUR	745125.778	679112.66
R6	FOUR	745015.174	678921.12
R7	FOUR	744914.408	678920.994
R8	FOUR	744642.115	679101.984
R9	FOUR	744752.945	679112.196
R10	FOUR	744874.252	678800.058
R11	FOUR	744693.087	678628.578
R12	FOUR	744400.077	679262.865
R13	FOUR	744591.595	679212.734
Ahiabron R1	FOUR	750198.847	675492.506
R2	FOUR	750169.448	674837.689
R3	FOUR	749382.503	675602.282
R4	FOUR	749392.452	675703.03

		R5	FOUR
748827.972	675853.421		
ZLF	FOUR	756702.479	649834.155

Waste logistic collection and disposal points for the Nhyiaso sub metro

LOCATION	TYPE OF MODEL USED	CORDINATES	
		NORTHINGS	EASTINGS
Sialabi Hospital	FOUR	751929.478	677509.385
Tafo Pankrono estate	FOUR	751203.926	677538.694
R1	FOUR	751849.005	677398.476
R2	FOUR	751687.792	677388.2
R3	FOUR	751576.937	677398.135
R4	FOUR	752855.576	678266.051
R5	FOUR	753127.681	678236.172
R6	FOUR	753389.432	678427.893
R7	FOUR	756539.192	681816.416
R8	FOUR	757718.66	681404.876
R9	FOUR	752016.884	680138.656
R10	FOUR	751672.648	681457.846
R11	FOUR	750051.08	680841.362
R12	FOUR	750039.947	681697.597
R13	FOUR	750322.426	681425.961
R14	FOUR	750322.563	681315.152
R15	FOUR	750312.735	681113.67
R16	FOUR	750343.4	680761.136
R17	FOUR	750353.951	680378.356
R18	FOUR	750625.843	680519.722
R19	FOUR	750706.506	680479.528
R20	FOUR	751774.185	680833.42
R21	FOUR	751753.646	681145.671
R22	FOUR	751884.467	681286.86
R23	FOUR	752206.942	681267.111
R24	FOUR	752327.811	681307.554

ZLF	FOUR	756702.479	649834.155

Waste logistic collection and disposal points for the Asawase sub metro

LOCATION	TYPE OF MODEL USED	CORDINATES	
		NORTHINGS	EASTINGS
Abuobo No2 CP	THREE	734806.808	563401.501
Closest Res	THREE	734710.881	683844.768
R2	THREE	734650.397	683864.843
R3	THREE	734580.082	683683.419
R4	THREE	734580.314	683492.006
R5	THREE	734741.575	683461.979
R6	THREE	735073.685	683804.91
R7	THREE	735174.34	683895.701
R8	THREE	734730.985	683885.09
KMALF	THREE	709115.645	684559.526
Abuobo No2 CP	THREE		
Closest Res	THREE	735497.51	683301.708
R1	THREE	735467.256	683321.819
R2	THREE	735910.489	683433.175
R3	THREE	736444.766	683252.487
R4	THREE	735557.419	683755.125
R5	THREE	735708.567	683755.308
R6	THREE	735869.67	683856.246
R7	THREE	735849.517	683856.222
R8	THREE	735970.276	683987.334
R9	THREE	735940.022	684007.446
KMALF	THREE	709115.645	684559.526
Abuobo No2 CP	THREE	735193.665	684580.779
Closest super market	THREE	735264.164	684611.088
R1	THREE	735092.729	684721.698
R2	THREE	734931.456	684761.801
R3	THREE	735123.056	684641.14
Last Res	THREE	734750.456	684449.277
KMALF	THREE	709115.645	684559.526
Adukrom CP	THREE	736975.281	686184.735
R1	THREE	736592.168	686355.537
R2	THREE	736380.754	686194.096
R3	THREE	736239.659	686214.075

R6	THREE	736128.069	686838.546
R7	THREE	736238.826	686909.199
R8	THREE	736510.868	686929.672
R9	THREE	736661.992	686950.001
KMALF	THREE	709115.645	684559.526
R4	THREE	736199.425	686153.581
R5	THREE	735947.198	686415.21

Waste logistic collection and disposal points for the Nhyaiso sub metro

LOCATION	TYPE OF MODEL USED	CORDINATES	
Daban	FOUR	NORTHINGS	EASTINGS
R1	FOUR	714609.886	674268.916
R2	FOUR	714458.75	674258.651
R3	FOUR	714479.296	673946.334
R4	FOUR	714218.04	673361.623
R5	FOUR	714258.779	673019.105
R6	FOUR	714147.898	673049.191
R7	FOUR	713583.649	673018.253
R8	FOUR	713260.78	673350.342
R9	FOUR	712977.965	673883.995
R10	FOUR	713009.336	672977.226
R11	FOUR	713019.54	672876.483
R12	FOUR	713020.202	672352.55
R13	FOUR	712667.688	672221.12
R14	FOUR	712596.91	672412.469
R15	FOUR	712636.758	672775.243
R16	FOUR	712636.313	673127.891
R17	FOUR	718480.807	673064.737
R18	FOUR	712555.434	673339.378
R19	FOUR	712041.656	673237.974
R20	FOUR	711759.614	673157.013
R21	FOUR	711688.457	673650.634

R22	FOUR	711789.223	673650.76
R23	FOUR	711507.079	673650.406

R24	FOUR	710559.997	673558.534
R25	FOUR	710811.355	674002.183
R26	FOUR	711174.148	673972.411
R27	FOUR	711133.438	674294.784
R28	FOUR	711466.343	673992.929
R29	FOUR	711728.346	673983.182
R30	FOUR	712100.799	674285.921
R31	FOUR	712162.081	673631.078
R32	FOUR	712393.74	673711.974
R33	FOUR	712645.73	673651.837
R34	FOUR	712635.274	673954.094
R35	FOUR	713542.455	673723.494
KMALF	FOUR	709115.645	684559.526

Waste logistic collection and disposal points for the Nhyiaso sub metro

LOCATION	TYPE OF MODEL USED	CORDINATES	
Santanse		NORTHINGS	EASTINGS
Store	FOUR	717532.187	666313.015
R1	FOUR	717018.438	666191.441
R2	FOUR	717038.879	665969.807
R3	FOUR	717271.074	665637.62
R4	FOUR	717382.035	665547.086
R5	FOUR	717875.802	665537.655
R6	FOUR	718308.859	665719.577
R7	FOUR	718248.019	666011.684
R8	FOUR	718187.612	665971.304
R9	FOUR	717925.778	665850.058
R10	FOUR	717875.303	665920.52
R11	FOUR	716766.667	666080.283

R12	FOUR	716877.864	665808.39
R13	FOUR	716998.783	665808.548
R14	FOUR	717150.444	665415.803
R15	FOUR	717100.918	664760.833
R16	FOUR	717332.679	664761.137
R17	FOUR	716546.797	664689.58
R18	FOUR	716224.649	664457.421
R19	FOUR	715730.895	664456.774
R20	FOUR	715690.272	664698.534
R21	FOUR	715609.132	665101.45
R22	FOUR	716172.909	665495.131
R23	FOUR	714107.206	665492.438
R24	FOUR	714306.422	667276.08
R25	FOUR	712451.796	667686.786
R26	FOUR	713289.156	666912.04
Durbin New Site			
R1	FOUR	712810.961	670488.287
R2	FOUR	713343.175	671939.857
R3	FOUR	713725.701	672242.61
R4	FOUR	713987.628	672293.32
R5	FOUR	714138.789	672283.436
R6	FOUR	713997.475	672474.693
R7	FOUR	713523.826	672514.397
R8	FOUR	713472.832	672997.962
R9	FOUR	713482.655	673199.487
R10	FOUR	713694.034	673381.114
KMALF Site			
Q1	FOUR	709085.704	684317.671
Q2	FOUR	708924.504	684297.327
Q3	FOUR	708732.955	684377.704
Q4	FOUR	708762.991	684538.953
Q1	FOUR	708944.32	684579.473
Land filling	FOUR	709115.645	684559.526

Waste logistic collection and disposal points for the Kwadaso sub metro

LOCATION	TYPE OF MODEL USED	CORDINATES	
Durban New site	FOUR	NORTHINGS	EASTINGS
R1	FOUR	717430.437	674977.735
R2	FOUR	717682.805	674615.337
R3	FOUR	717803.964	674424.057
R4	FOUR	718096.121	674474.801
R5	FOUR	718197.9	673668.901
R6	FOUR	717865.59	673497.201
R7	FOUR	716988.663	673707.679
R8	FOUR	716807.018	673919.034
R9	FOUR	716463.504	674644.034
R10	FOUR	717219.018	674826.339
R11	FOUR	717310.049	674554.417
R12	FOUR	717532.201	674181.907
R13	FOUR	717623.029	674071.192
R14	FOUR	717764.38	673849.711
R15	FOUR	716956.234	675460.76
R16	FOUR	716190.529	675369.125
Asafo Agyei Hospital	FOUR	715576.074	675197.074
R17	FOUR	715334.375	675085.941
R18	FOUR	715182.975	675287.262
R19	FOUR	714957.553	670269.363
R20	FOUR	714916.733	670672.333
R21	FOUR	715137.994	671005.108
R22	FOUR	715112.918	674904.305
R23	FOUR	715204.238	674400.644
R24	FOUR	715365.425	674431.072
R25	FOUR	715537.056	674169.325

R26	FOUR	715577.526	674038.394
KMALF	FOUR	709115.645	684559.526

APPENDIX D

Statistics

Age of respondent

N	Valid	180
	Missing	0
Mean		31.6667
Mode		25.00
Std. Deviation		1.20107E1
Minimum		14.00
Maximum		78.00

APPENDIX E

Paired Samples Test

	Type of model	Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Model 2 – Model 4	-1.15000	.93330	.20869	-1.58680	-.71320	-5.510	19	.000
Pair 2	Model 1 - Model 4	1.15000	.93330	.20869	.71320	1.58680	5.510	19	.000
Pair 3	Model 1 – Model 3	.70000	1.08094	.24170	.19411	1.20589	2.896	19	.009
Pair 4	Model 2 – Model 3	-.70000	1.08094	.24170	-1.20589	-.19411	-2.896	19	.009 .206

Pair 5	Model 3 – Model 4	-.45000	1.53811	.34393	-1.16986	.26986	-1.308	19