KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA

Efficiency of Solid Waste Collection Services: Case Study of Kumasi Metropolis

by

John Korfeh Thomas (B.Sc. Chemistry)

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DECLARATION

I hereby declare that this submission is my own work towards the M.Sc. and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

John Korfeh Thomas	……………………	…………………
(PG 9728313)	Signature	Date

Certified by:

Dr. Sampson Oduro Kwarteng	……………………	…………………
Supervisor	Signature	Date

Certified by:

Prof. Y. A. Tuffour	……………………	…………………
(Head of Department)	Signature	Date

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DEDICATION

This Thesis is dedicated to the Almighty God, my family and friends.

ABSTRACT

Indiscriminate dumping, irregular collection of waste generated and inadequate resources are the key problems facing solid waste management in the Kumasi Metropolis. This study was carried out in order to determine the efficiency of three out of seven solid waste collection companies (A, B, C) in the Kumasi Metropolis through the assessment of their scope of operations, operational efficiency regarding time spent and trips made and operational cost as it related to customers‘ satisfaction. Survey tools used for this study included questionnaires, key informant interviews and mapping of operational zones. The study identified the various pickup points, distances between pickup points, haul distances, haul times, quantity of waste collected, operational cost and customers‘ satisfaction for both communal and house to house collection services. Major conclusions drawn from the study were distribution of both communal skips and house to house bins influenced resources, hence the efficiency of collection; the three companies were 73.42% (58 tonnnes) efficient of total solid waste (79 tonnes) previously collected and deposited at the landfill per day based on records obtained from the landfill; the communal collection minimum and maximum pickup up times (mins) per skip were determined to be 8 and 18 respectively while the minimum and maximum house to house collection pickup times (mins) per household bin picked were calculated to be 1.26 and 1.29 as well as 100 and 207 per trip respectively; companies which collected higher number of household bins and communal skips at low pickup time were efficient; Companies which served higher number of customers were found to operate at the minimum cost, thus efficient; cost of collection for house to house service was determined to be higher than that of communal service; more customers were satisfied with services of companies which operated at minimum cost. It is hereby recommended that further study should be carried out in other operational zones of the selected solid waste companies to find out if the collection and cost efficiency will be the same as determined by this study; KMA to conduct periodic checks for both solid waste collection companies and communal caretakers to ensure that they operate according to standards; customers of both communal and house to house services should be educated on domestic management of solid waste; the weighbridge to be repaired or replaced for measurement accuracy of solid waste at the landfill; the solid waste collection companies should be encouraged to increase the quantity of solid waste to be collected; and the project for the construction of sheds with concrete floors at the various communal skip sites should continue so as to prevent leachate from seeping into soils during rains.

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LIST OF ACRONYMS

Acronym	Meaning
EGSSAA	Environmental Guidelines for Small-Scale Activities in Africa
EPA	Environmental Protection Agency
GEPA	Ghana Environmental Protection Agency
GPS	Global Positioning System
ISWA	Integrated Solid Waste Management
KMA	Kumasi Metropolitan Assembly
KMWL	Kumasi Metropolitan Waste Limited
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
PSE	Public Sector Efficiency
PSP	Public Sector Performance
SW	Solid Waste
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environmental Program
US	United States
WHO	World Health Organisation
WM	Waste Management

CHAPTER 1: INTRODUCTION

1.1 Background

Municipal solid waste (MSW) management is one of the serious problems confronting urban governments in most developing countries. The quantity of solid waste (SW) that needs managing is continuously increasing as a result of many factors of which population growth, rapid urbanization, increasing availability of consumer products, improving living standards as a result of economic growth and poverty reduction are keys. Accelerating urbanization has increased the burden on municipal governments of providing universal and efficient MSW collection services (Beede and Bloom, 1995). Waste disposal did not pose any problem in the early days since there was enough space for habitation. Shafiul and Mansoor (2003) mentioned that waste disposal became problematic with the rise of cities and towns where a lot of people began to congregate in relatively small areas in pursuance of accommodation and livelihoods. While densities of population in urban cities and per capita waste generation increased, the available land for waste disposal decreased proportionally. In this regard, solid waste management has become a very important sector in keeping urban cities clean and healthy.

The terminology Solid waste management refers to the separation from source, storage of waste, collection of waste and its transport to final disposal site in a manner that is environmentally friendly and sustainable. Thus solid waste management is an essential environmental health service as well as an integral part of basic urban services. This is due to the fact that implications of poor waste management can be extremely damaging when people are exposed to the unsanitary condition. Some diseases such as typhoid, malaria, cholera and dysentery are all as a result of improper management of waste and as a result human resources can be lost which will be needed in the country‘s development. The responsibility of collection, transfer and the disposal of waste has greatly been assumed by governments in the metropolis in both developing and developed world.

Solid waste management remains a major challenge to most governments in developing countries in view of the increasing volumes of waste materials generated and disposed to the environment in urban areas. Due to this a lot of governments have welcomed the idea of public private partnerships to aid in improving the efficiency and effectiveness in the delivery of waste management services. The system in Ghana as in most countries with developing economies has often been characterized by inadequate collection services, little or no treatment and uncontrolled dumping (McDougall et al., 2001). Despite the fact that MSW management services in countries with developing economies draws a significant share of municipal budget, it is unreliable and provide inadequate coverage to support improvement in public health and the environment (Bartone, 1999). Although most governments in developing countries in Africa for example are noted to spend about 20-50% of their budget on SWM, only 20-80% of the waste is collected (Achankeng, 2003).

Assessment of the efficiency of solid waste management also serves as a measurement of how successful waste management organizations are. In this light, the achievement of the intended output and improvement thereof of these waste companies has always been a subject of immense interest to economic theorists and policy makers alike. As argued by the pioneer of complex efficiency measures Farrell (1957) mentions that, ―If the theoretical arguments as to the relative efficiency of different economic systems are to be subjected to empirical testing, it is essential to be able to make some actual measurements of efficiency. Equally, if economic planning is to concern itself with particular industries, it is important to know how far a given industry can be expected to increase its output by simply increasing its efficiency, without absorbing further resources‖.

Efficient solid waste management can manifest in an integrated solid waste concept which aims at preventing waste, minimizing the initial generation of materials through source reduction, reusing and recycling, and composting to reduce the volume of materials being sent to landfill (Babanawo, 2006). This type of solid waste management will avoid or minimize significantly serious public health, environmental and social problems associated with the communities under consideration.

1.2 Problem Statement

Reliable information on issues pertaining to how efficient MSW management firms carry out operation within their operational jurisdiction is very important to the overall development and improvement of solid waste management. However, information regarding how efficient MSW is managed within the Kumasi Metropolis is not readily available. More so, solid waste disposal has become major problem in the Kumasi Metropolis which leads to indiscriminate dumping of waste. In light of this, it is important to investigate the level of efficiency with which the solid waste collection companies operate.

1.3 Justification

Management of solid waste in an efficient way is a key factor in promoting the development of a municipality by reducing the amount of financial investment allocated to solid waste management. Efficient management of solid waste management also improves public health and environmental sanitation. Information on the efficiency of solid waste management when readily available could influence municipal planning and developments. This research therefore seeks to measure and investigate the efficiency of solid waste collection services in the Kumasi Metropolitan Assembly.

1.4 Objectives

The overall objective is to determine the efficiency of companies involved with solid waste collection services within the Kumasi Metropolis. The specific objectives are:

1) To identify and map up zones, types and survey the scopes of operation of selected solid waste collection companies.
2) To assess the operational efficiency of solid waste collection with respect to time spent and trips made during collection.
3) To assess cost efficiency of the solid waste collection and customers satisfaction.

CHAPTER 2: LITERATURE REVIEW

2.1 Solid Waste

Solid waste means any garbage, refuse, or sludge from a wastewater treatment plant, water supply, treatment plant, air pollution control facility and other discarded materials including solid materials resulting from industrial, commercial, mining and agricultural operations (New York State Department of Environmental Conservation, 2011).

2.1.1 Brief Overview of Solid Waste and National Development

One of the negative effects of increased prosperity is an escalation in the quantities of wastes produced. Waste or garbage is any material generated by human activity that is considered useless, superfluous, valueless or unwanted and is disposed of in the environment. After collection, this waste may be dumped into landfill sites or destined for composting, incineration or recycling. Solid waste generated in urban centres may contain both domestic and commercial waste, along with industrial waste, thus constituting a complex mixture of different substances, of which some are hazardous to health (Awortwi, 2004).

Yahaya and Illoris (2010) asserts that one of the greatest threats to national development of most developing countries has been the increasing generation of municipal or urban waste mainly attributed to rapid urbanization. Though there has been increased attention given by government in recent years to handle this problem in a safe and hygienic manner through MSW management programmes (MSWM), it is still getting off hands. In its scope, municipal or urban solid waste management includes all administrative, financial, legal, planning, and engineering functions involved in the whole spectrum of solutions to problems of solid wastes thrust upon the community by its inhabitants (Tchobanaglous *et al.*, 1997). The solid waste management includes various techniques such as thermal treatment, biological treatment, land filling and recycling (Kontos *et al*., 2005).

2.2 Municipal Solid Waste Management

MSW refers to solid waste produced by households, commercial entities (excluding industries) and institutions. They are highly heterogeneous and are influenced by socio-geographical factors (Gershman, et al., 1986). MSW is defined to include refuse from households, non-hazardous solid waste from industrial, commercial and institutional establishments (including hospitals), markets waste, yard waste and street sweepings (Shubeler et al., 1996). The sources of municipal wastes are given in Table 2.2 below

Table 2.1 Sources of municipal solid waste

Source	**Examples**
Residential	Single family homes, duplexes, town houses, apartments
Commercial	Office buildings, shopping malls, warehouses, hotels, airports, restaurants
Industrial	Packaging of components, office wastes, lunchroom and restroom wastes (but not industrial process wastes)
Institutional	Schools, medical facilities, prisons

Source: Tchnobanoglous, *et al*., 2002

2.2.1 Concepts and Drivers of Municipal Solid Waste Management Systems

In order to meet the goals of MSWM, concepts have evolved to drive the approach taken by many communities. The key concept identified worldwide currently determining the structure of waste management is the concept of sustainable waste management. Sustainable MSWM seeks to approach MSWM based on the principles of sustainable development. The major framework on which sustainable MSWM is developed is the Waste Hierarchy and Integrated Solid Waste Management (ISWA and UNEP, 2002).

The waste hierarchy presented as a stepwise approach to waste management in order of environmental priority for different waste management options (ISWA and UNEP, 2002). This was introduced in Agenda 21 (declaration on environment and development adopted by more than 178 Governments at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil, 3 to 14 June 1992). The general principle of the waste management hierarchy consists of the following steps (ISWA and UNEP, 2002): Minimizing wastes; Maximizing environmentally sound waste reuse and recycling; Promoting environmentally sound waste disposal and treatment; extending waste service coverage.

Most developed countries have generally accepted this hierarchy as a strategy towards an environmentally sound waste management system. This is reflected in the waste management policies of these nations. Strange (2002) asserts that based on past experiences of unplanned and uncoordinated ways of managing waste there is the need for approaching society‘s use of resources and ways of managing in a sustainable way. Schertenleib and Meyer (1992b) highlighted the interrelated nature of the different components (collection, recycling and disposal) of a solid waste management scheme; in that changes in one of the components may often lead to or aggravate the problems of the other components. The importance of managing solid waste through an integrated approach is discussed by the UNEP International

Environmental Technology Centre (2005) as follows:

1. Some problems can be solved more easily in combination with other aspects of the waste management system than individually;

2. Adjustments to one area of the waste system can disrupt existing practices in another area, unless the changes are made in a coordinated manner;
3. Integration allows for capacity or resources to be completely used; economies of scale for equipment or management infrastructure can often only be achieved when all of the waste in a region is managed as part of a single system;
4. Public, private, and informal sectors can be included in the WM plan;
5. An ISWM plan helps identify and select low cost alternatives;
6. Without an ISWM plan, some important aspects of the waste management system that does not generate revenue may not be given proper attention leading to negative effects of the system on public health and safety.

This line of thinking has been widely adopted in the WM study and practice culminating in the evolution of different definitions and concepts aimed at integrating WM system elements, aspects and dimensions. The term IWM is often used to describe an approach in which decisions on waste policies and practices take account of waste streams, collection treatment and disposal methods, environmental benefits, economic optimization and social acceptability (McDougall et al., 2001). The concept of IWM, according to McDougall et al. (2001), takes an overall approach and manages waste in an environmentally effective, economically affordable and socially acceptable way. It is said to involve the use of a range of different treatment options at a local level and considers the entire solid waste stream. IWM can be defined as ―the selection and application of suitable techniques, technologies, and management programs to achieve specific waste management objectives and goals‖ (Tchobanoglous and Kreith, 2001). Two available frameworks that explain how to approach ISWM are the IWM Model (McDougall et al., 2001) and Integrated Sustainable Waste Management (van de Klundert and Anschütz, 2001).

2.3 Early Practices of Solid Waste Management (In Ghana)

Collected waste is disposed off in waste dumps all over the country (Ghana). Although covering of waste with soil at authorized waste dumps, rodent and vector control operations are daily operations, most facilities that are engineered are not properly designed (Babanawo, 2006). They are either old quarries or natural depressions which have been used as waste disposal sites. In smaller towns and rural areas most households dispose off waste in abandoned clay or sand pits (Babanawo, 2006). Solid waste is ultimately disposed in both unauthorized and authorized dumping sites. Different types of waste regardless of their nature is indiscriminately dumped in old quarries, drains, beaches and sand pits without considering the negative effects it will have on the environment (GEPA, 2002).

2.3.1 Solid Waste Categories

Solid waste categorization is usually associated with its generation and collection points. People associate waste collection with the periodic collection of household waste. However, the problem is more complex. Besides residential customers, waste companies also have industrial customers, whose requirements differ from typical residential wishes. Industrial customers typically produce larger amounts of waste, which requires another pick-up system. In addition, the collection of recyclables is becoming increasingly important in a society where resources are perishable and environmental concern is growing. Table 2.2 describes the categories of wastes in relation to their sources of generation:

Table 2.2 Categories of Solid Waste

Type of solid waste	Typical facilities, activities, or locations where wastes are generated	Source
Spoiled food wastes, agricultural wastes, rubbish, and hazardous wastes	Field and row crops, orchards, vineyards, diaries, feedlots, farms, etc	Agricultural
Industrial process wastes, scrap materials, etc.; nonindustrial waste including food waste, rubbish, ashes, demolition and construction wastes, special wastes, and hazardous waste.	Construction, fabrication, light and heavy manufacturing, refineries, chemical plants, power plants, demolition, etc.	Industrial
Paper, cardboard, plastics, wood, food wastes, glass, metal wastes, ashes, special wastes, etc.	Stores, restaurants, markets, office buildings, hotels, auto repair shops,	Commercial Institutional
Special waste, rubbish, general waste, paper, plastics, metals, food waste, etc.	Includes residential, commercial and Institutions	MSW

Source: Hester *et al*., 2002

2.4 Contemporary Methods of Solid Waste Management

2.4.1 Sanitary landfill

A common practice in many areas of the country (Ghana), until recently, was open dumping. Public pressure forced most communities to switch to sanitary landfill as the standard method of disposal. Whiles landfill improves the aesthetic and environmental quality of disposal sites, other environmental problems such as groundwater contamination can occur at an improperly operated site (Gershman, et al., 1986). In an attempt to remedy the environmental threat of MSW disposal sites, there is a law in the US giving EPA the authority to close open dumps and to upgrade the quality of landfills. Disposal cost has escalated during the past decade for several reasons. Public demand for environmentally sound disposal practices and the need to locate landfill areas distant from population center are two important factors that have contributed to the cost increase (Gershman, et al., 1986). Lack of engineering measures, lack of leachate management plan and no consideration for landfill gas management are the characteristic features of an open dump. Other features include absent of operational measures such as registration of users, control of number of tipping front and compaction of waste (Zeerbock, 2003).

Solid waste disposal has always been an intractable problem in Ghana for some many years. Open dumps that serve primarily as landfill have no gas recovery or leachate system in place and most of these are located at areas that are sensitive ecologically as well as hydro logically. Sanitary operations that take place at such places are also below standard, thus they do not meet the required standards. Inadequate budget allocation for operation and maintenance is always the problem. This leads to unsafe and substandard facilities that serve as a threat to the health of the populace and becomes an aesthetic burden to the community people and the metropolitan at large. Mensah and Larbi (2003) mentioned that it is estimated that about 10% of all solid waste generated in the country are disposed off properly.

In the last few years problems with solid waste disposal have assumed increased prominence as a political issue especially in the urban areas. With low central government budgets and weak capacity for internally generated funds, most District Assemblies find sustained operation of controlled landfill sites a real burden. However, there is a real need for improvement in current levels of operations and in the design and siting of new facilities to ameliorate current levels of environmental degradation (Mensah and Larbi, 2005).

According to Kreith, (1994) there are simply no combinations of waste management techniques that do not require land filling to make them work. He also mentioned that some waste are not recyclable, many waste that can be recycled eventually get to a point where their intrinsic value is dissipated completely and they are unable to be recovered, and residuals become the products of recycling.

2.4.2 Recycling

Recycling of bio-degradable domestic waste into nutrient stable compost can result in both reduction of waste and reduction in water pollution through substitution of chemical fertilizers by compost in urban agriculture. In a case study of urban agriculture farmers in Harare, Kisner (2008) recommended that the current farming practices of using chemical fertilizers were leading to underground water pollution through eutrophication and leaching. The composting of MSW and availing of such compost to urban agriculture farmers could assist in pollution mitigation.

Though high- and low-value recyclables are typically recovered and reused, these make up only a small proportion of the total waste stream. The great majority of the waste (70 %) is organic. In theory, this waste could be converted to compost or used to generate biogas, but in situations where rudimentary solid waste management systems barely function, it is difficult to promote innovation, even when it is potentially cost-effective to do so. In addition, hazardous and infectious materials are discarded along with general waste throughout the continent. This is an especially dangerous condition that complicates the waste management problem (EGSSAA, 2009). Recycling turns materials that would otherwise become waste into valuable resources. Collecting used bottles. Cans, and newspapers and taking them to the curb or to a collection facility is just the first in a series of steps that generates a host of financial, environmental, and social returns. Some of these benefits accrue locally as well as globally (US EPA, 2011).

2.4.3 Composting

During the last few years, composting has gained wide acceptance as a key component of integral solid waste management. However, a vigorous debate continues about what materials should be composted, and in particular, whether composting should be limited to organic waste separated at their source (by individual households) or applied more broadly to mixed MSW (Richard and Woodbury, 1998). European Union the average biodegradable waste generated from households was 40% (Wullt, 2010). In the Kenyan Capital, Nairobi, Muniafu and Otiato (2007) reported a biodegradable component of 40% of the total MSW. In one of the cities in Ghana, Kumasi, Ketibuah et al. (2010) indicated that the majority of waste from household is identified as organic waste which includes putrescible waste and food waste.

There are several important tradeoffs between these approaches, including the quantity of material diverted from landfills, the quality of the final compost, the impact on recycling and the cost (Richard and Woodbury, 1998). Mensah and Larbi (2005) stated that, conditions in Ghana are very conducive for composting in terms of 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. The largest known composting plant in the country was commissioned in the early 1980s and was built with external donor support. At its early years of operation it helped reduce the large volume of waste but cost of maintaining its operation was very high and this affected its sustainability. Most of its mechanical components have currently been decommissioned and its main purse of operation is just for the purpose of demonstration (Mensah and Larbi, 2005).

2.4.4 Source reduction

Several methods exist at national level which can be employed to lessen waste production. Such methods include encouraging the use of disposable material which should be minimal necessary to achieve the desired level convenience and safety: redesign of packaging; promotion of producer responsibility for post- consumer waste and increasing consumer awareness of waste reduction (UNEP 1996). Measures such as the creation of market forces and economic incentives as well as including these in the legislative action would serve as a wheel to drive forward such reforms. However, the method and its applicability would depend on each situation and its current circumstances. (Zerbock, 2003).

The best effective way to promote waste reduction is firstly not to create it. By reducing waste production and promoting reusing industry as well as consumers can reduce waste management cost as well as saving the natural environment and the resources. The amount of waste generated has been increasing in the USA. According to the US EPA (2011) between 1960 and 2009 waste generated by one person increased from 2.7 to 4.3 pounds per day. This leads to about 243 million tons of waste generated in 2009 in the USA. Source reduction of prevention of waste is the most effective strategy for reducing and re-using waste by manufacturing, purchasing and designing by using materials that have minimum amount of toxicity of trash that will be created. The fewer natural resources are used when less waste is generated

(US EPA, 2011). A major part of waste prevention strategy is the method of reuse, stopping waste at the source by preventing or delaying a materials entry into the waste collection and disposal system. Reduction at source refers to the modification of design manufacture use or purchase of material or products (including packaging) in a way to reduce their amount before they become toxic before they become MSW.

Reduction of source refers to the reuse of materials or products.

2.4.5 Incineration

As mentioned by Mensah and Larbi (2005) the national policy encourages the construction of incineration plants on a small scale for the disposal and treatment option for hazardous waste as well as health care. Most towns that have health facilities have small scale incinerators that have been built as part of the health care infrastructure provided. Such facilities use simple designs with cement blocks, metal and lateritic bricks. The most common energy source is local firewood and this is easily maintained and operated by the District environmental health staff (Mensah and Larbi, 2005). 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).

2.4.6 Controlled dumping

Controlled dumping refers to the use of landfills as terminal endpoints for refuse. It is the preferred method of disposal in many towns in most developing countries because it is the most affordable and requires the least maintenance. The sanitation policies recommend that dumping and covering should be the preferred option for rural areas and small towns. Controlled dumping sites are located in depressed areas such as borrow pits, valleys, ravines and surface mining areas. River banks also serve as illegal dumping site in other communities. The standard of maintenance and operation on these sites generally is not sufficient. Often there are no mechanical equipments for compaction of waste, spreading which means there will be little reduction in volume of waste compacted. Rodent and fly control are often ignored since littering is also a serious problem on such sites (Mensah and Larbi, 2005).

2.5 Current Solid Waste Management Processes

The term solid waste management has been viewed differently by various authors. Kumah (2007) defines solid waste management as ―the administration of activities that provide for the collection, source separation, storage, transportation, transfer, processing, treatment, and disposal of waste‖. However, Tchobanoglous et al. (1993) provide a more comprehensive definition of solid waste management. Solid waste management is defined by Tchobanoglous et al. (1993) as: ―the discipline associated with the control of waste generation, its storage, waste collection, its transfer as well as transport, processing and disposal in a way that agrees with best principles of conservation, economics, public health engineering, aesthetics and other environmental that is also responsive to public behavior and attitudes‖.

In view of this, if the management of solid waste is to be accomplished in an orderly and efficient way, the basic aspects and other relationships that are involved must be understood after being clearly identified (Tchobanoglous et al, 1993). As a result of this the management of solid waste management takes into account the following: storage, source separation, collection, transportation and disposal of municipal solid waste in a sustainable and environmentally friendly manner.

These are some of the six key elements illustrated in Figure 2.1 below.

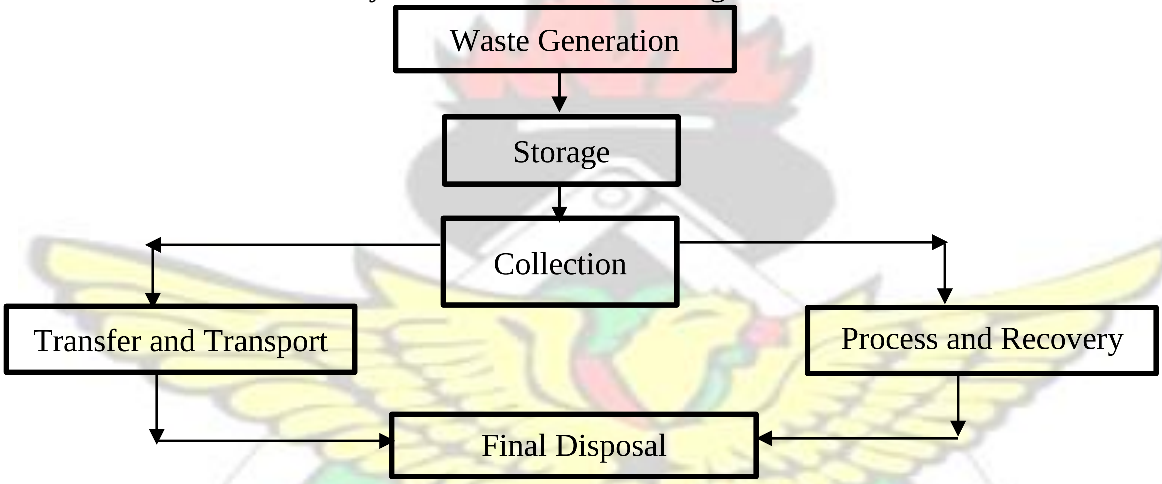

Figure 2.1: Key Elements of Solid Waste Management

As depicted in figure 2.1 above, the major elements in management of solid waste in more logical order includes waste generation, storage, transfer and transport, collection, processing and recovery and final disposal. This implies that when solid waste is generated it is first stored in either skips or dustbins. It is collected and disposed of in a landfill as a final step. More so, collected waste can be transferred from small collection equipment to big waste collection trucks for final disposal at the landfill site.

Additionally, waste collected can be processed after collection and recovered for materials to be reused. The elements are further discussed below.

2.5.1 Waste Generation

Generation of solid waste includes activities that have identified materials as not being of value and are either gathered for disposal or thrown away (Momoh and Oladebeye, 2010). As mentioned by UNEP (2009) in 2006 the total amount of generated MSW worldwide reached 2.02 billion tones, which represented a 7% yearly increase since 2003. Further it was estimated that between 2011 and 2007, the generation of municipal waste globally will increase by 37.3 %, which was equivalent to roughly 8 % increase per annum (UNEP, 2009). More so as per WHO predictions that total healthcare waste per person per annum in countries with low income ranges between 3.0kg and 0.5kg. This notwithstanding the increase and its causes should have been further and properly explained by the organisations. It is accepted as indicated by UNEP (2009) that the generation of solid waste is rapidly increasing at a global level as Mensah and Larbi (2005) confirmed this concerning Ghana solid waste generation

2.5.2 Solid Waste Storage

Storage of solid waste is simply explained by Tchobanoglous et al. (1977) to mean where solid waste is stored before it is collected. This could be in a form of a dustbin or skip which is not thrown away indiscriminately. Storage, according to Tchobanoglous et al. (1977), is of primary importance due to aesthetic reasons.

2.5.3 Collection of Solid Waste

Solid waste collection does not only include its gathering but also it includes its hauling to the final destination after tit has been collected where it is emptied (Kreith, 1994).

The most common types of residential collection service in countries such as America include setout-setback, backyard carry and the curb system. USPS (2000) mentions that in Thimphu in Bhutan, solid waste collection from commercial and household's setup was done in concrete tanks which was placed at vantage points and later conveyed by big waste collection trucks. There were also areas where containers and concrete buns provided at various location from where waste were lifted for disposal. Bins and containers were also placed alongside shops in some areas which were directly emptied in to tippers. This helped to prevent people from indiscriminately dumping waste. On the other hand construction of such concrete tanks and containers are expensive to construct in Ghana and in KMA to be specific

2.5.4 Solid Waste Transfer and Transport:

Transfer and transport of solid waste according to Kreith (1994), involves two main steps: (1) the transfer of municipal solid wastes from the smaller collection vehicle like tricycles to the larger transport equipment and (2) the subsequent transport of the wastes, usually over long distances to the landfill or final disposal site.

2.5.5 Processing and Recovery

A successful processing and recovery of solid waste includes all the equipment facilities and technology that are needed to enhance the efficiency and effectiveness of other functional elements to be able to recover materials that can be reused, and conversion products such as energy from solid waste (Tchobanoglous et al, 1977). In the recovery attempt, separate operations have to be devised to help recover resources that are valuable from the mixed solid waste delivered to solid waste processing plants (Tchobanoglous *et al.*, 1977).

2.5.6 Disposal

This is the final stage of all solid wastes whether they are commercial or residential wastes collected and directly transported to landfill site or final disposal site. The next section further analyses into details the method of final disposal of solid waste. Various methods of management of solid waste over the years have emerged. According to the Centre for Environment and Development (2003) these methods vary greatly with local conditions and types of wastes. The most common means of solid waste disposal in the final stage is the disposal at the well-engineered landfill site which should be situated over 1000 meters away from human settlement as a result of health and aesthetic factors.

2.6 Problems of Managing Solid Waste

A typical solid waste management system in a developing country according to Ogawa (2005) displays an array of problems, including irregular collection services, crude open dumping and burning without air and water pollution control and low collection coverage. Further he grouped these challenges into social, technical, institutional and financial factors and discussed these constraints in relation to the sustainability of solid waste management in developing countries like Ghana.

2.6.1 Financial Factors

Solid waste management according to Ogawa (2005) in developing countries is given a very low priority, except perhaps in large and capital cities. This leads to the availability of very limited funds to be allocated by the government to the solid waste management sector, and the levels of services required for protection of the environment and public health are not attained. The problem at the local government level is acute where there are inadequately local taxation systems and therefore, the financial basis for public services, including solid waste management, is weak. The weak financial basis of local governments can however be supplemented by the collection of charges as part as fee for user service. The ability for users to pay for the services is very limited in poorer and developing countries, and their willingness to pay for the services which are ineffective and irregular.

2.6.2 Technical Factors

Kreith (1994) makes mention that in most developing countries human resources are inadequate at both the local and national levels with technical expertise necessary for the management of waste management operation and planning. Most officers that are responsible for the management of solid waste management, especially at the local level, have very minimum or no technical background or training in management engineering.

2.6.3 Institutional Factors

On institutional constraints, Ogawa (2005) indicated that, lack of effective legislation for solid waste management, which is a norm in most developing countries, is partially responsible for the roles or functions of the relevant national agencies not being clearly defined and the lack of coordination among them. However, as these facilities are usually considered unwanted installations and create not-in-my-backyard (NIMBY) syndromes among the residents, no local government is willing to locate them within its boundary (Ogawa, 2005).

2.7 Solid Waste Management in Ghana

Most developing countries like Ghana are faced with serious solid waste management problems. Solid waste is disposed of ultimately in both unauthorized and authorized waste dumps sites all over the country. All kinds of wastes, regardless of their type and nature, are indiscriminately dumped into sand pits, depressions, old quarries, drains, beaches and even in certain areas, along streets, not considering the nuisance and harm that is being caused to the environment and public health (GEPA, 2002).

Each household on a daily basis generates garbage or waste items that are no longer needed or which are not being used. These are considered to be in the category of waste and we tend to throw them away (Danso, 2011). As indicated by Danso (2011) in the 2000 Population and Housing Census, Ghana_s population was 18.9 million, with a daily average waste generation per capita of 0.45 kg, Ghana annually generates about 3.0 million tons of solid waste. The capital Accra, and the second largest city Kumasi, with a combined population of about 4 million and a floating population of about 2.5 million generate over 3,000 tons of solid waste daily. Danso (2011) made mention that generation levels of solid waste in the country can be classified into different types using their source as the basis of comparison, thus: public waste, household waste, industrial waste, (Saw dust/wood shavings, and metal scraps), biomedical waste, institutional waste from institutions such as schools, offices, stores, department, hospital waste (Surgical waste, swabs materials), or general waste (in markets, lorry parks, open spaces, streets).

2.7.1 Collection and Disposal of Solid Waste

Collection of home waste by waste collection companies is limited to high and some middle income areas while those who are poor are left to handle the problem on their own. As a result of this disposal of waste indiscriminately in canals, streams and surface drains take place, creating environments that are unsightly and unsanitary in most parts of Ghana, especially the urban cities (Danso, 2011). Waste disposal conditions in Ghana are generally similar to those in the tropical climates in developing countries. Even though the use of open dumps is strongly discouraged by the national policy for use as landfills, most landfill in Ghana are open dumps. Danso (2011) also mentions that most methods used for disposal of solid waste are: compositing, sanitary land filling, incineration and uncontrolled dumping of refuse at open sites.

2.7.2 Environmental issues

The decomposition of waste into constituent chemicals is a common source of local environmental pollution. This problem is especially acute in developing nations; very few existing landfills in the world_s poorest countries would meet environmental standards accepted in industrialized nations, and with limited budgets there are likely to be few sites rigorously evaluated prior to use in the future (Zerbock, 2003). In the absence of proper methane venting and/or flaring, the gas seeps into porous soil surrounding the waste and eventually migrates into basements and homes, posing an explosion risk. Carbon dioxide is a second predominant gas emitted by landfills; although less reactive, buildup in nearby homes could be a cause of asphyxiation (Zerbock, 2003).

Solid waste handling and disposal in all countries to some degree have associated health risks, but certain problems are more widespread and acute in nations that are underdeveloped. Cointreau (1982) has classified these into four main categories: presence of potentially hazardous industrial waste, presence of human fecal matter systems, the air pollution caused by consistently releasing methane and burning dumps and the decomposition of solids into constituent chemicals which contaminate air and water

Every solid waste system has human fecal matter present; the problem varies in developing nations with the prevalence of adequate sanitary disposal systems such as outhouses, municipal sewerage or on-site septic systems (Zerbock, 2003). Zerbock (2003) indicates that in areas of developing countries where such facilities are absent (especially over-crowded municipal districts and shanty towns), the solid waste stream is likely to have a high amount of human fecal matter present. The usual pathway for diseases include placing or using hands that are contaminated in eating or in the mouth, by directly inhaling airborne dust particles contaminated with pollutants or through vector insects such as mosquitoes or cockroaches (Zerbock, 2003).

2.7.3 Public Sector Solid Waste Management

Public sector solid waste management is a service for which local government is responsible for the provision of waste management services to the benefit of the whole public. The services provided can be enjoyed by any resident without diminishing the benefit to anyone else. Solid waste management being an urban issue, the level of government responsibility is typically local or an issue of the Metropolitan Government (Cointreau-Levine, 1994). The Government remains responsible to ensure that a service is provided, and that it meets required standards in terms of reliability, efficiency, customer relation and environmental protection (Cointreau-Levine and Coad, 2000). The work of Abankwa *et al*. (2009) indicated that, the waste management department of AMA has generally relegated direct collection of solid waste to the private sector, itself concentrating on supervision of waste collection, monitoring of partnership system put in place, and management of final disposal points.

2.7.4 Private Sector Solid Waste Management

Privatization is the gradual process of disassociating state-owned enterprises or stateprovided services from government control and subsidies, and replacing them with market-driven entities (EGSSAA, 2009). In the context of municipal services, privatization generally implies reducing local government activity within a given sector by involving participation from the private sector; or reducing government ownership, through divestiture of enterprises to unregulated private ownership, and commercialization of local government agencies (EGSSAA, 2009). Private sector participation in solid waste management concerns the involvement of companies, organizations or individuals in solid waste management in a Municipality, Metropolis or a District. Privatization usually arises as a result of the existing service delivery being costly or inadequate (Cointreau-Levine, 1994).

2.8 Solid Waste Management in Kumasi Metropolis

Solid waste collection companies in Kumasi are KMWL, Asadu, Vemark, Zoomlion Ghana Limited, Sak-M and Aryetey Brother Company Limited (ABC). This service is delivered under various conditions by the private sector. This service delivery has two types of collection that are employed.

2.8.1 House to House Solid Waste Collection

Meskworld Limited (ML), Waste Group Ghana Limited (WGG), Sak-M Company Limited (SAK-Mo), Kumasi Waste Management Limited (KWML) and Aryetey Brother Company Limited (ABC), are the contractors responsible for the delivery of house to house solid waste collection services. However, about 33% of the population enjoys this service with irregular service payment. This service is operated on a franchise basis for a fee of GHC5.00 to GHC30.00 per house on monthly basis. Under this scheme no cost is attributed to KMA. The impact of the services, however, as well as its efficiency is affected as a result of the scattered nature of the areas of service.

2.8.2 Communal Solid Waste Collection

Waste Group Ghana Limited (WGG), Meskword (ML) Aryetey Brother Company Limited (ABC) and Kumasi Waste Management Limited (KWML) are the contractors involved in providing this service. The total quantities collected are weighed at the final disposal site or landfill and payment is based on a rate of GHC10.00 per tonne. The collection system for the communal service entails the provision of metal containers (skips) at designated sites known as transfer stations, which are shared by a number of houses within that community or area. The houses are responsible for keeping the transfer station neat at all times. Full communal skips are transported and emptied at the final disposal site by skip loaders. Households mostly dispose waste indiscriminately when there are no communal bins or skips.

The Ghana Central Government through the Ministry of Local Government Rural Development and Environment used to assist KMA in the payment of municipal solid waste contractors, which per month is almost 2 billion which represents an average of 600 tons of collected waste in a day. When the central government withdraws its assistance in paying contractors, the metropolitan would have no option but to mobilise funds in order to sustain operations.

2.8.3 Collection (Institutional and Industrial Premises)

Collection Institutional and industrial collection relies on services that are container based, such services include limited areas of the Kwame Nkrumah University of Science and Technology campus. Here the Health Services Unit is in charge of collection from residential halls and bungalows using a side loading truck. The limited collection from a number of private clinics, however, is carried out by the use of side loading trucks in which the domestic household refuses are mixed with clinical waste.

2.8.4 Current Disposal Operations

A sanitary site (properly engineered) currently in use at Dompoase where, refuse is covered at the site after it has been compacted. Attached to a control room is a weighbridge where the refuse is inspected and weighed before being accepted into the landfill. At the site, offices and a maintenance bay are available. Heavy-duty machines and equipment which are used for spreading of waste, compaction and covering are available at the site. Gravelling and grading of access routes are other vital activities that take place at the landfill site at Dompoase.

2.8.5 Current Challenges in Solid Waste Management in Kumasi Metropolis

Currently solid waste management in Kumasi Metropolis is facing some challenges. These challenges include inadequate equipment holding culminating in limited coverage of service delivery, inadequate byelaws and lack of enforcement of available ones and inadequate funding for capital investment for effective delivery of waste management services. Also another challenge encountered by KMA solid waste management is inadequate revenue mobilization to finance Waste Management Service costs (Kumah, 2007). Some bad attitude of residents such as indiscriminate disposal of household waste and littering due to lack of waste collection points, ineffective environmental health education and service promotion strategy, poor design of communal containers, poor infrastructural condition particularly road networks in new settlements, which negatively impacts on service delivery. Furthermore the high reach of containers leads to most of the waste carried especially by children being thrown on the ground.

2.9 Approaches to Solid Waste Collection Efficiency Measurement

While in the 1950s the options of efficiency measurement in economics were found to be limited to essentially simple ratios computed from basic financial statements (Farrell, 1957), nowadays a wide array of tools is available, including even macrolevel measures capable of capturing the public sector as a whole the public sector performance (PSP) or the public sector efficiency (PSE) indicators (Afonso et al., 2005). However, in determining the efficiency of solid waste collection services, vehicle efficiency could be calculated (Peavey et al., 1985).

2.9.1 Calculation of Vehicle Efficiency

The expected output for vehicles involved in solid waste collection can be calculated using the approach proposed by Peavey et al. (1985) where different subsequent set of equations was used in their environmental engineering program. They stated that, by separating the collection activities into unit operations, it is easier to develop design data relationships that can be used to establish vehicle requirements for the various collection systems, thus communal and house to house collection systems. They further divided activities involved in waste collection into four main unit operations as stated below

Pick up time (P): This is the time spent picking up a loaded container plus the required time to deposit the empty container in the case of a communal system; or the time spent loading the collection vehicle beginning with the stopping of the vehicle prior to loading the contents of the first container and ending when the contents of the last container to be emptied has been loaded in the case of a house to house collection system.

Haul (h): This is time taken to reach the disposal site starting after the point of finishing loading last container plus that required for vehicle to reach first container to be loaded on the second trip. This time excludes time spent at disposal site

At Site time (S): This is the time spent at disposal site including that spent waiting to unload plus time spent unloading.

Off Route (W): This includes all time spent on activities that are non-productive from the point of view of the overall collection operation. Such activates include unauthorized coffee breaks, talking to friends, unavoidable congestion and equipment repair.

2.10 Strategies to Improve Solid Waste Collection Cost Efficiency

Cost efficiency can be defined as the productive use of a system in relation to the cost involved in operating the system. In solid waste management various strategies can be adapted to improve efficiency of collection. These strategies include reducing the collection frequency, making collection fast, motivating employees and also contracting or introducing completion in collection services.

2.10.1 Collection Frequency: Less Is Often Best

When it comes to picking up MSW and recyclables, less is often best. Offering collection services less often can, in many cases, decrease costs and increase the amount of waste diverted from disposal. Although twice per-week pickup is still popular in many parts of the country more and more communities are successfully making the change to weekly pickup (Alfonso et al. 2010). Studies show that reducing MSW collection frequency ensures the following, although impacts of changing frequency of collection vary.

Decreases vehicle and labor needs: When collection frequency is reduced, the need for MSW collection vehicle is cut by 20 to 40 percent. More so few trucks use leads to savings in maintenance cost, saving in labor and capital cost.; A study carried by

Kemper and Quigley (1976) relating to the economics of refuse collection revealed that vehicle and labor needs directly increase as collection frequency increases. However, if collection frequency is minimized vehicle and labor need are also minimized.

Decreases costs: When frequency of collection is reduced, operation cost is also lowered and this improves the productivity of operations. With frequent collection being less, residents set out more waste for each collection which makes trips of vehicles more productive.

Reduces environmental impacts: Reducing collection frequency means fewer trucks, lower fuel usage, fewer air emissions as well as reduced traffic and safety impacts on community streets.

Provides opportunities for new or expanded services: Reducing collection frequency helps to establish or expand recyclables or yard-trimmings collection programs. Municipalities can implement new programs while still preventing fleet and staffing increases.

Increases waste diversion: Reducing collection frequency increases participation in diversion programs for recyclables and yard-trimmings. Callan and Thomas (2001) indicates that when households are not frequently served with waste collection services, they amount of waste generated over time decreases, due to the fact that households tend to recycle recyclables instead of dumping them in the trash bin.

Balances workload: Reducing collection frequency increases collection route productivity by spreading out the total amount of residential MSW to be picked up each week more evenly among the available work days. Deliverables for a solid waste collection is proportionally shared and executed when too much time and resources are not allocated to only collection of solid waste from municipalities (Dijkgraaf *et al.*, 2003).

2.10.2 Making Collection Faster and Easier

Once hailed as ―tomorrow‗s key to improving collection efficiency,‖ automation is today‗s solution to making collection more cost-effective. Traditionally, collecting MSW is a labor-intensive business, often requiring as many as three workers per vehicle to lift and dump disposal containers (Babanawo, 2006). With the advent of automated lifting systems, however, collection requires fewer workers, thereby reducing labor costs and workers‗ compensation claims. Making collection faster and easier has benefits such as:

Reduced injury risk: Increased automation typically reduces work-related lifting injuries as well as puncture wounds and lacerations.

Reduced vehicle needs: Fully automated collection increases (by up to 300 percent) the number of households served per worker, per hour. This increased productivity typically results in a smaller vehicle fleet.

Decreased labor needs: Automated collection reduces crew size per truck. For semiautomated collection, one- or two-person crews are the norm. With fully automated systems, the driver typically works alone.

Reduced environmental impacts: Automated collection means fewer trucks, lower fuel usage, fewer air emissions, and fewer traffic and safety impacts on community streets.

Reduced tipping fees: Carts with lids help keep water, ice, and snow from set-outs, which also helps control the weight of set-outs and decreases tipping fees.

Improved neighborhood aesthetics: Uniform containers eliminate unsightly setouts. Containers with lids are less likely to be tipped over or torn apart by animals, reducing litter potential.

Reduced public health risks: Containers with lids help mitigate odor and health concerns.

2.10.3 Crew Productivity (Motivating Employees)

Automated trucks and altered collection schedules only go so far in improving collection efficiency. Efficient collection programs also need a motivated, productive work force. To increase worker productivity, many local governments implement special pay structures, offer better training programs, and reward employees for safe work practices. Improving management practices and increasing communication and cooperation between labor and management improves a wide range of public services (Bartone, 1999). In fact, focusing on employee motivation can accomplish the following:

Improved work/life quality: Help to increase excitement about work, improve problem-solving abilities, and reduce injury potential.

Reduced costs: Help to decrease overtime and absenteeism, increase productivity, and allow service improvements to be made with limited resources.

Improved labor/management relations: Help to reduce grievances, develop fair and effective discipline, share gains, and develop labor agreements that more accurately reflect service needs.

Improved safety: Help to focus on injury and accident prevention, improve training and policies, improve return-to-work rates, and reduce time-loss expenses.

2.10.4 Contracting: Competition and Collection Costs

Privatization increases the cost-effectiveness of many public programs. Faced with consumer demand for cheaper and better service, many municipalities outsource the collection of solid waste and recyclables. Shafuil and Mansoor (2003) state that when privatizing, a well-designed and carefully managed contract is the key to getting reasonable rates and high-quality service. Some of the benefits of competition typically include:

Reduced costs: Competition often reduces costs to customers. Rates have been known to drop as much as 20 to 60 percent as a result of a competitive bidding process, especially if collection services have not been bid out for a long time.

Improved service quality: Competition, and a carefully designed scope of services, ensures customers get the best possible service. Some communities use a combination of public and private crews. The competition between these service providers keeps all parties ―on their toes.‖

Increased control of waste flow: The U.S. Supreme Court ruled that local governments cannot pass ordinances directing MSW to particular facilities. Courts have, however, upheld the rights of communities to enter into open competitive processes to select collection contractors and specify, as part of those processes, that collected materials be taken to designated sites.

CHAPTER 3: METHODOLOGY

3.1 Profile of the Study Area

Kumasi the capital city of Ashanti Region in Ghana was founded by Osei Tutu I in the 1680's to serve as the capital of the Asante Kingdom (Fynn, 1971). Due to its political dominance and strategic location, Kumasi had all the commercial trade routes converging on it hence turned into a major commercial center (Dickson, 1969). However, in 1890 it was colonized and ruled by the British (Adu Boahen, 1965). The city of Kumasi began to grow and expand becoming the second to Accra in terms of population size, economic activity, social life and land size.

Its greenery and beautiful layout has made it to be considered as the ―Garden City of West Africa‖. The three major communities, thus Bompata, Adum, and Kropo, have grown and been populated in a concentric form to span an area of approximately a radial distance of ten (10) kilometers. Originally the direction of growth in Kumasi was along the arterial roads as a result of the accessibility the roads offer leading to a development pattern which is radial. The city has a rapid growth rate of 2.7 per cent annually (Regional Statistical Office, Kumasi, the year 2010). The city is made up of about 90 suburbs most of which were absorbed into the city due to the process of physical expansion as a result of growth. The population in 2000 during the population census was at 1,170,270. However, it was projected in 2006 to be 1,610,867 and has further been projected in 2009 to be 1,889,934.

Location and Size

The city of Kumasi is geographically located in the forest transitional zone and is about 270km north of Accra, the national capital. It lies between latitude 6.35^0 – 6.40^0 and longitude 1.30^0 – 1.35^0, an elevation range between 250 – 300 meters above sea level with a coverage area of about 254 square kilometers.

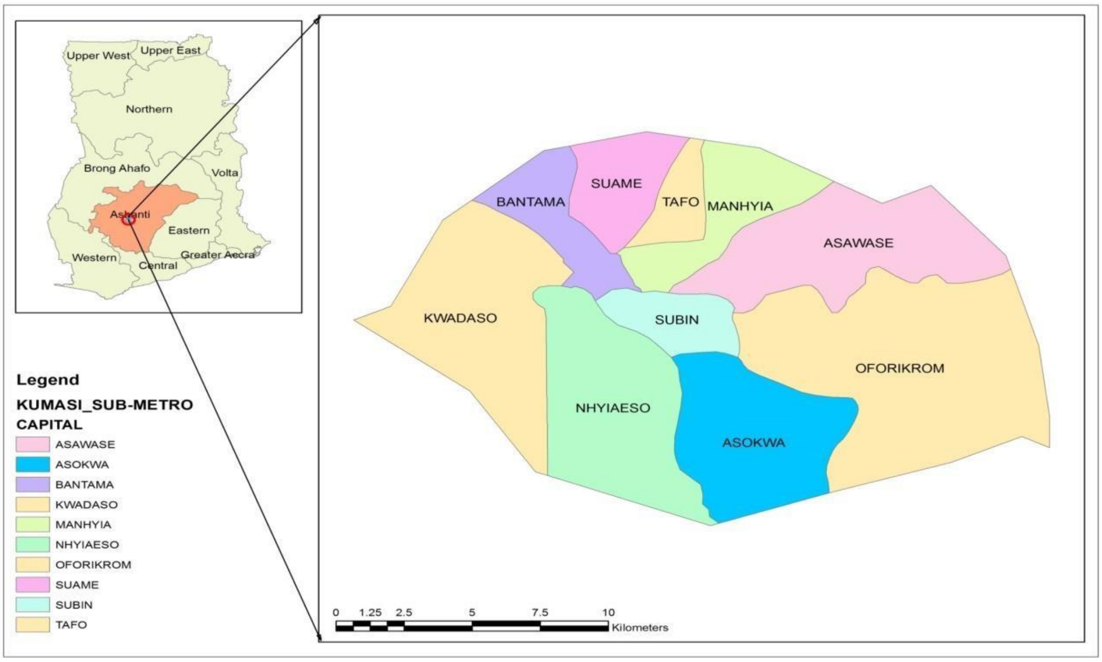

Figure 3.1: Map of Study Area

Source: http://www.ghanadistricts.com

Climate

The Kumasi Metropolis lies within the wet sub-equatorial category. The average maximum average temperature is 30.70^{0}C and a minimum temperature is about 21.5^0. The average humidity is about 60 per cent at 1500 GMT and about 84.16 per cent at 0900 GMT. The moderate temperature and humidity and the double maxima rainfall regime (165.2mm in September and 214.3mm in June) have a direct effect on the environment as well as the population growth as it has precipitated effect on the influx of individuals from every part of the country and even beyond its frontiers to the metropolis. This is a result of the fact that the climatic conditions are friendly.

Drainage and Relief

The Kumasi Metropolis can be found within the plateau of the South–West physical region with an undulating topography which ranges from 250-300 metres above sea level. The city is traversed by major streams and rivers, which include the Nsuben, Subin, Wiwi, Sisai, Owabi, and Aboabo. Biotic activity, however, in terms of indiscriminate waste disposal practices, encroachment and estate development have negatively impacted on the drainage system of the capital city and these water have been brought to the brink of extinction as a result of this.

Vegetation

The metropolis is located within the South-East Ecological Zone which is moist and semi-deciduous. Ceiba, Triplochlon, and Celtis are the predominant tree species found with other exotic species. Agriculture in the periphery has been promoted as a result of the rich soil. The Kumasi Zoological Gardens was developed as a result of the vegetation that was reserved within the city, which is located opposite to the Kejetia Lorry Terminal and adjacent to the Ghana National Cultural Centre. This has served as a centre of tourist attraction. There are other patches of vegetation cover apart from the zoological gardens which are scattered over the peri-urban areas of the metropolis. However, most of these nature reserves have been depleted as a result of the rapid state of urbanization.

3.2 Data Collection

3.2.1 Indicators for Solid Waste Collection Efficiency

Different indicators were used to assess the efficiency of solid waste collection by companies in the metropolis. The following were a list of indicators that were used and their significance:

Number of Trips per day: This is the number of trips of solid collection vehicle was able to collect and dispose to Dompoase landfill facility in a day. It was an indicator for how much a vehicle was able to deliver per day.

Waste sources: The sources of municipal solid waste included households, commercial entities or institutions.

Efficiency of truck: This was the average of all daily weights of waste disposed at the landfill by the trucks within a specified period. This was dependent on the number of trips made per day, it measured the vehicles productivity.

Productivity of collection crew: This was the ratio of the daily output of collection vehicles divided by the number of collection crew assigned to vehicles in different companies. It measured the productivity of collection gang. It thus showed their level of motivation and supervision of field collection. This included the total quantity of solid waste collected and disposed of at the landfilled by each vehicle divided by total number of crew members for each waste collection company on the daily basis.

Waste managers: These oversee all solid waste and city cleanliness operations. They identify, pilot and implement new sold waste strategies that improve efficiency.

Capacities of companies: This was obtained by number of vehicles owned by each company times the established capacity or output (waste disposed of) per day for each type of vehicle. It identified the capacities of companies to perform the required services.

Maintenance of Vehicles: This included schedules and facilities owned the service company for maintenance and repairing of collection vehicles. It served as prerequisite for the reduction of vehicle breakdown and increased service life for vehicles.

Revenue/Expenditure Ratio: It was the ratio of revenue received to the expenses incurred by the companies. It also measured the profitability of services rendered.

Unit Cost for collection services: This was the ratio of total expenses incurred by the companies to the total output in tonnes made with these resources. It gave a rough estimate of cost of services across the companies and their efficiency of operation

3.3 Survey Tools

The survey tools included sampling by which the three companies and their respective operational zones were selected and data collection which included use of handheld GPS Devices, questionnaire, key informant interviews and monitoring of trucks movement.

Out of seven (7) waste collection companies in the Kumasi metropolis, three waste collection companies (Asadu Royal Waste, ZoomLion and Vermark) were randomly sampled and one operational zone (oforikron, Tafo, and Kwadaso) was respectively selected for each of the three solid waste collection companies. Two types of questionnaires were developed to help obtain first-hand information about the operations of all seven (7) solid waste collection firms from the waste companies and also from their customers. Since written and electronic records of the solid waste collection companies were available, random selection was used to select 3 out of the 7 solid waste collection companies in the metropolis. Questionnaires for solid waste collection companies were divided into two sections. The first (1) section focused on solid waste collection services and the second (2) section focused on cost of providing their services. Questionnaires for households had two sections. The first (1) section focused on solid waste collection services they received and the second (2) section focused on the satisfaction of users about services provided. Developed questionnaire for household respondents was pretested on the field to identify all possible challenges pertaining to understanding of the questions by both the interviewer and the respondent.

A total number of 140 respondents for each selected operational zone were interviewed (Table 3.1).

Table 3.1 Total number of selected respondents in operational zones

Solid Waste Collection Company	**Selected Operational Zone**	**Service Provided**	**No of Respondents**
Company A Waste Company (Asadu)	Oforikrom	House to house Collection	70
		Communal Collection	70

Company B Waste Company limited (Vermark)	Kwadaso	House to house Collection	70
		Communal Collection	70
Company C Waste Company (ZoomLion)	Tafo	House to house Collection	70
		Communal Collection	70

Additional data collection form was developed to record the time taken for operations of a skip truck in communal and house to house collection systems. Forms designed for communal collection system as well as house to house collection system included; Pick up time (P), Haul time (h), at site time (s), and weight-time-distance chart.

Key informant interviews were also carried out with various key stakeholders regarding the collection of solid waste in the metropolis.

3.3.1 Mapping Operational Zones

Handheld GPS devices were used by Enumerators to pick the coordinates of the location of both communal skips during communal collection service and location of various houses that were served during the house to house waste collection (Plate 3.1). GPS coordinates were later transferred to a Microsoft Excel format. Operational zones were mapped for both

Communal skip containers storage sites and house to house bin pickup points and these storage sites pickup points are represented by dots (points) on each map representing each zone (Figures 4.2 to 4.8).

Plate 3.1 Enumerator recording the GPS coordinates of a communal skip

3.3.2 Assessment of Collection Efficiency and Data Analysis

Data collection teams recorded the times spent for the provision of communal and house to house solid waste collection services on data collection forms. This was carried on for a period of one week within each selected operational zone for each selected solid waste collection company within the Kumasi Metropolis. This was done by riding the collection vehicles along with the solid waste collection staff daily during waste collection period (Plate 3.2).

Plate 3.2. Data collection team member riding with house to house waste collection staff

3.4 Data Analysis

Framework and formulae were used to determine operational and cost efficiency of selected solid waste collection companies. The framework was used as a projection to show efficiency of each of the three waste collection companies with respect to time spent and number of household bins and skip containers picked during collection. As per this framework, higher number of household bins and skip containers picked with low pickup time (house to house) and round trip time (communal) by any of the three companies would be considered efficient and the reverse of this would be regarded as inefficient (Figures 3.2 and 3.3).

The formulae were used to calculate and determine operational cost efficiency and pickup time (Table 3.2).

Increasing number of bins →

Increasing pickup time ↓

	Low Efficiency	High Efficiency
Low pickup time		High number of bins but low pickup time
High Pickup time	Low number of bins but high pick up time	

Figure 3.2: Framework for comparison of house to house collection efficiency

Increasing number of skips →

Increasing round trip time

	Low Efficiency	High Efficiency
Low round trip time		High number of skips but low roundtrip time
High Round trip time	Low number of skips but high round trip time	

Figure 3.3: Framework for comparison of communal collection efficiency

Table 3.2 Formulae used in calculating cost of operational efficiency

	Service Indicator	Formula	
		Communal Collection	House to House Collection

Efficiency of Service	Average pick up time/trip	Pt/CTn	Pt/HHTn
	Average Haul time/trip	Ht/ CTn	Ht/ HHTn
	Pick up time/bin	Pt/CSn	Pt/HHBn
Cost of Service	Cost/waste tonnage	Cd/CWt	Cd/HHWt
	Cost/trip	Cd/CTn	Cd/HHTn
	Crew Cost/day	CCm/CWd	CCm/HHWd
	Crew Cost/trip	CCd/CTn	CCd/HHTn

Pt=Total Pickup time (mins) Ht=Total Haul time

CSn=Number of communal skips HHBn=Number of household bins

CTn=Total number of communal trips/day Cd= Total Cost/day

HHTn=Total number of house to house trips/day CCm=Monthly Cost of collection crew

CWt=Total Communal waste collected CCd=Daily cost of collection crew

HHWt=Total house to house waste collected CWd=Communal collect. Days/week

HHWd=House to House collection days/week by collection crew

Av. Pt (Communa) (mins/skip/trip)=Loading time of waste + unloading time of empty skip

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Selected Companies and Operational Zones

For all operational zones in Kumasi Metropolis, Companies A (Asadu) and B (Vermark) had 3 compactor trucks and 2 skip trucks each while Company C (Zoom Lion) had 3 compactor trucks, 4 skip trucks and 1 roll on truck. However, only 1 compactor truck and 1 skip truck from each company were monitored during this study (Table 4.1).

Table 4.1. Selected Companies and Zones of Operation

Solid Waste Collection Company	Selected Operational Zone	Service Provided	No of Trucks
Company A Waste Company (Asadu)	Oforikrom	House to house Collection	1 Compactor truck
		Communal Collection	1 Skip truck
Company B Waste Company limited (Vermark)	Kwadaso	House to house Collection	1 Compactor truck
		Communal Collection	1 Skip truck
Company C Waste Company (Zoom Lion)	Tafo	House to house Collection	1 Compactor truck
		Communal Collection	1 Skip truck

Pattern for Communal Collection Service

Pattern for communal collection was the same for all the three solid waste collection companies selected within the metropolis. Collection started with an empty communal skip container on the skip truck from the parking lot of the solid waste collection company, which was then replaced with the full communal skip container on arrival at the first pick up point. The empty skip container was then disposed at the pickup point (skip site) and was used to replace the full communal skip container. The full skip container was picked and disposed or emptied at the final disposal site (landfill) and it was used to replace the full skip container at the second pickup point (Figure 4.1).

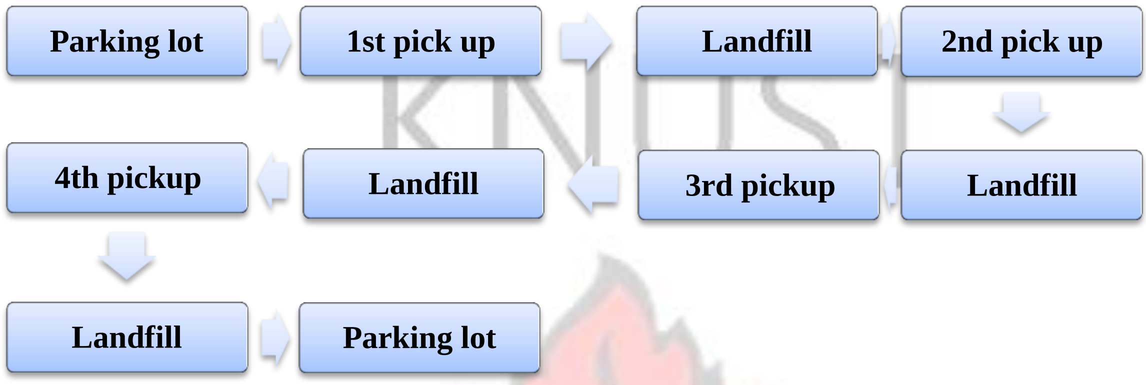

Figure 4.1: Collection pattern for communal waste collection

4.2 Mapped Communal Containers

Communal zones of operation for all selected solid waste collection companies were mapped to acquire the coordinates of all communal skip containers within the selected operational zones.

Communal skip containers within the operational zone of Company A Waste collection Company were mostly placed away from the major road. Only five out of nineteen communal skip containers were placed closed to the major road. Communal skip containers were spatially distributed within the operational zone. Most of the communal skip containers were close to each other except for the communal skip container located at Oduom Town. The possible implication of communal skip containers located further away from the major road was an increase in haul time for each communal trip as well as the time for the next pick up operation. This could then increase the overall collection time for communal collection, hence decreasing the number of trips per day. Improving the condition of roads connecting the various pickup points could serve as means of reducing the haul and round trip times during collection, thereby improving the operational efficiency for the three solid waste collection companies (Figure 4.2).

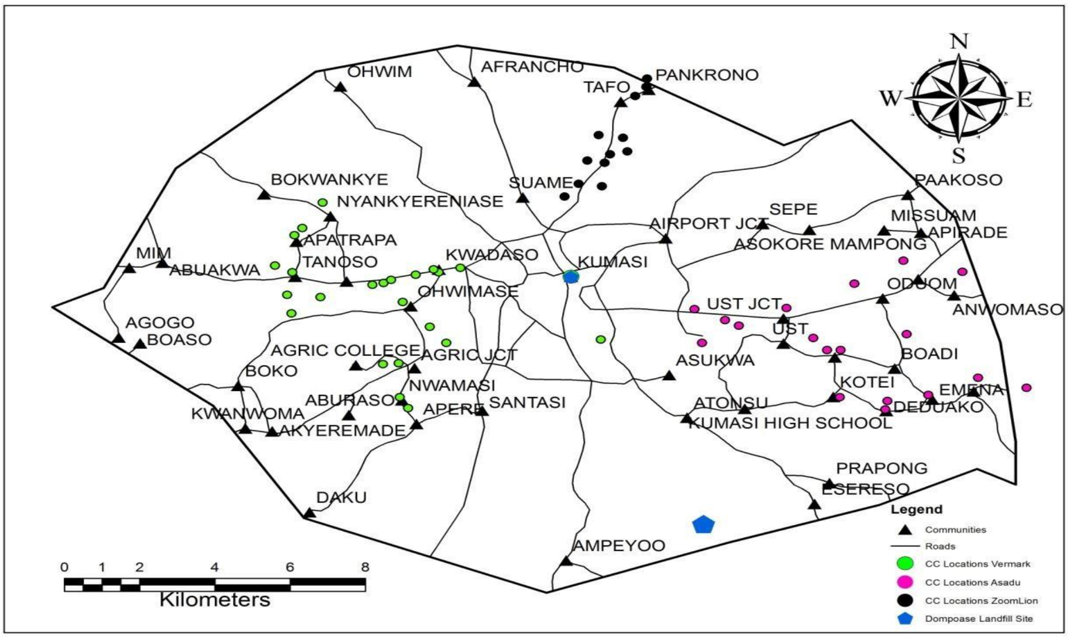

Figure 4.2: Communal Collection Sites for selected Waste Collection Companies

(Green=Comp B, Pink=Comp A, Black=Comp C, Blue= Dompoase Landfill)

Communal skip containers located in the operational zone for Company B Solid Waste Collection Company (green points) were mostly placed away from the main road. A total of twenty three (23) communal skip containers were located within the Kwadaso operational zone. Most of the skip containers were also close to each other with the skip container located at Abinkyi community being an exception and this was not significantly different from mapped communal skip containers for Company A Collection Company.

The twelve (12) Communal skip containers located within the operational zone for Company C Waste Company (black points) were all located close to the major road, unlike what was found for Company A and Company B Waste collection Companies. Also all communal skip containers were not far from one another communal skip container, with most of them being clustered at Tafo community. The closeness of skip containers to each other indicated that the coverage area or size of operational area was smaller as compared to the other two companies. Hence, time spent in hauling a communal skip container to the final disposal could be minimal as compared to other operational zones provided distance to the final disposal site was approximately the same from separate operational zones.

Communal skip containers placed at communal sanitary sites were of two different sizes, thus $12m^3$ for operational zones of Company A and Company B and $14m^3$ for Company C operational area. It was determined that Company B had better efficiency with respect to communal collection service due to the fact that it made highest number of trips per truck per day, picked up highest number of skip containers per day and collected and disposed highest quantity (tonnage) of solid waste per truck per day. Size of skip containers and number of skip containers picked per day determined quantity of waste collected per day and haul distance influenced haul time during collection. Companies A and C made the same number of trips per day but Company C collected higher quantity of solid waste based on the fact that Company C had bigger size of skip containers as compared to Company A. The quantity and spatial distribution of skip containers indicated the coverage and size of operational area (Table 4.2).

Table 4.2 Summary of Communal Collection Monitored

COMPANY:	Company A	Company B	Company C
Number of skip containers	19	23	12
Size of Skip containers (m3)	12	12	14
Number of skip trucks	1	1	1
Number of Trips/day	3	5	3
Haul Dist./Trip/Truck/Day (Km)	16	35	37
Tonnage/Truck/Day	11	19	13
Av. Skips containers Picked/day	3	5	3
Av. Pickup Time (mins/skip/day)	18	10	8
Round Trip Time (Mins)/Skip	52	51	57

4.2.1 Mapped House to House Storage Containers (Household Pickup points)

All household pickup points were mapped and customers that received house to house collection service were served for all the operational zones of the three solid waste collection companies (Figures 4.3 to 4.8 and Table 4.3). It was generally gathered that the total number of houses served was higher than the total pickup points identified and mapped. This indicated that averagely the minimum and maximum numbers of household bins picked per stop were 1 and 2 respectively which implied that number of household bins picked was directly proportional to the number of stops made and the quantity of waste collected and disposed of during the period of data collection (Table 4.3).

Company A

House to house collection for Company A Solid Waste Company took place at Bomso and Asuoyeboa communities. Most of the customers that received house to house collection service were located by the road in both communities. A total of 358 houses were served (145 houses in Asuoyeboa and 213 houses in Bomso) and 342 stops (199 stops in Bomso and 143 stops in Asuayeboa) were made during the period of data collection. This indicated that averagely, 0ne household bin was picked per stop (Figures 4.3 and 4.4).

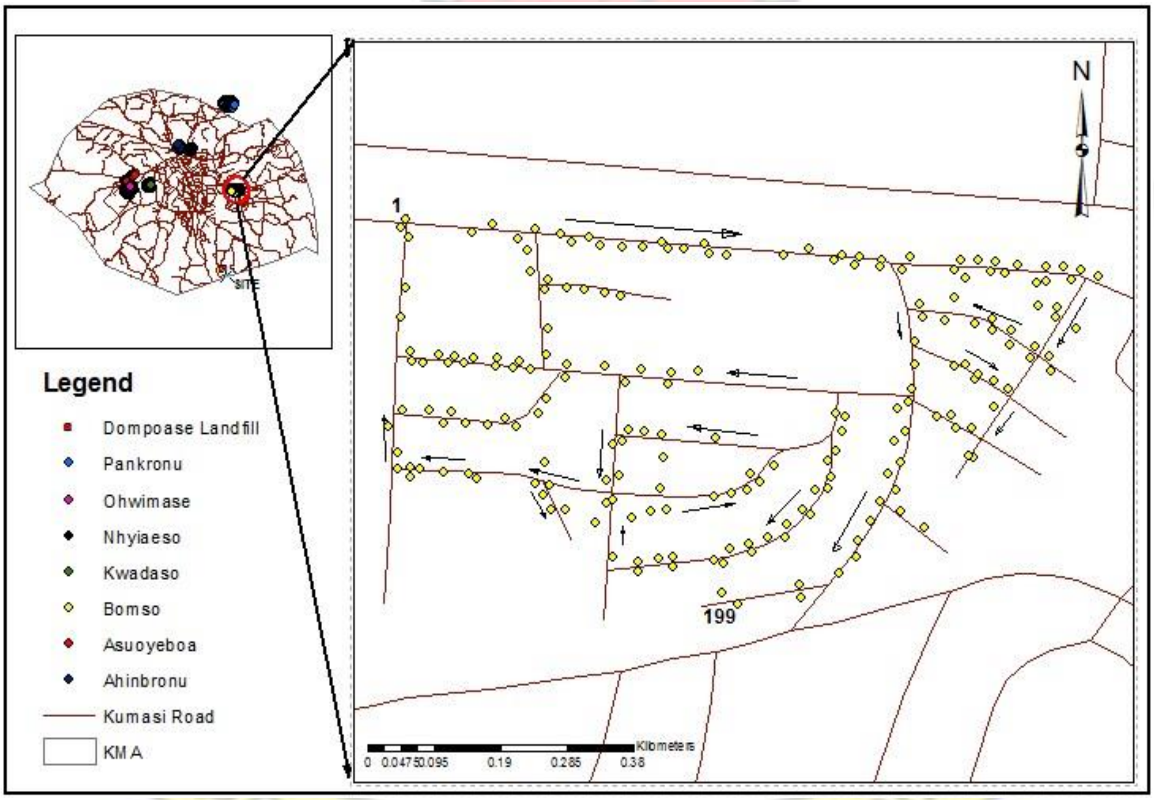

Figure 4.3: Company A House to House Collection - Bomso

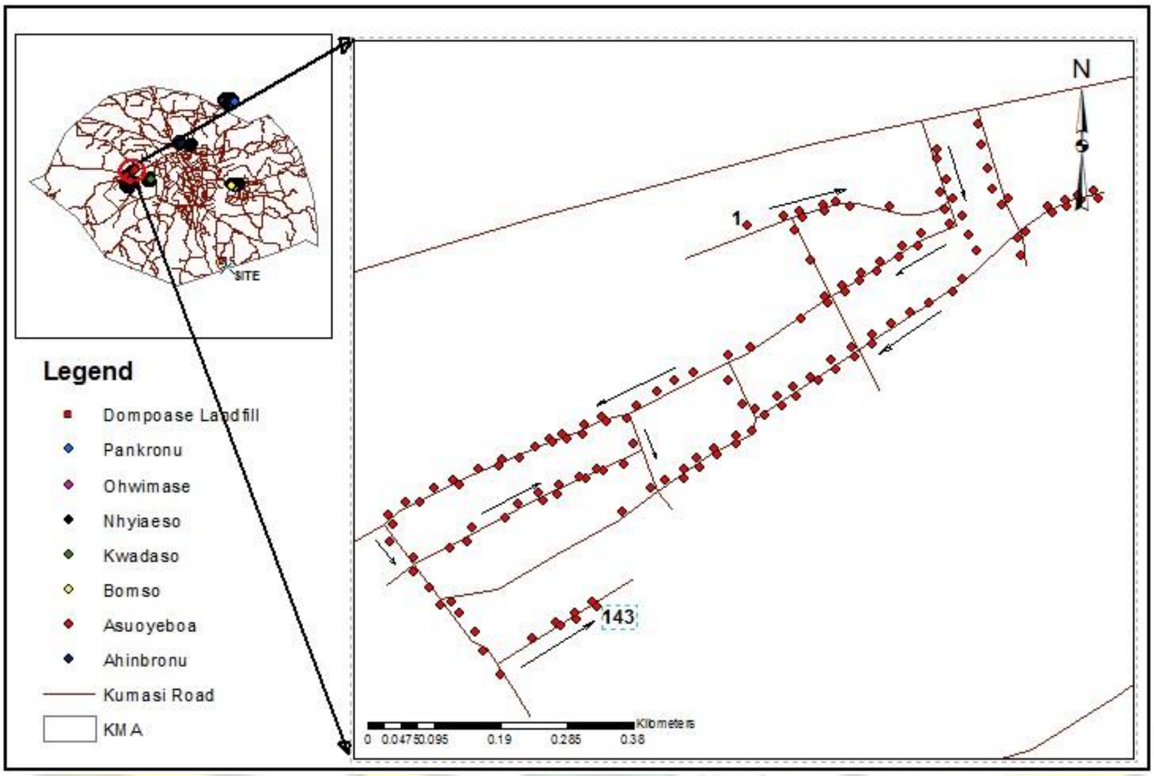

Figure 4.4: Company A House to House Collection –Asuoyeboa

Company B

House to house Collection solid waste collection service took place at Kwadaso and Ohwamase surburds. All houses served in Kwadaso were by the road, whereas some houses in Ohwamsase were not very close to road. In all 821 houses were served (497 houses at Kwadaso and 324 at Ohwamase) and a total of 456 stops (223 stops in Kwadaso and 233 stops in Ohwamase) were made. This indicated that on the average 2 household bins were picked per stop (Figures 4.5, 4.6 and Table 4.3).

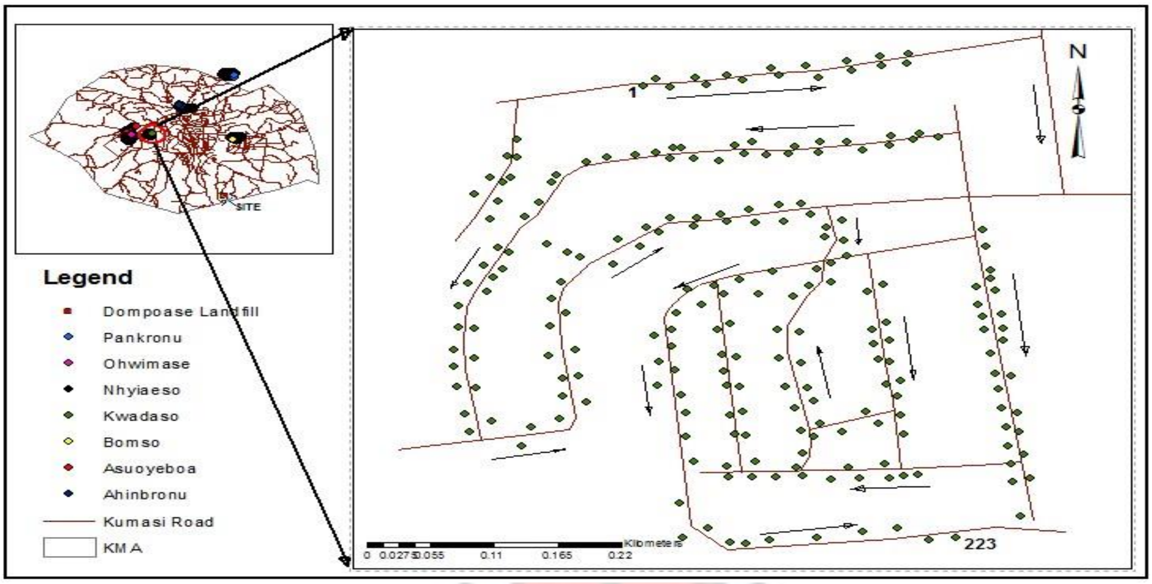

Figure 4.5: Company B House to House Collection-Kwadaso

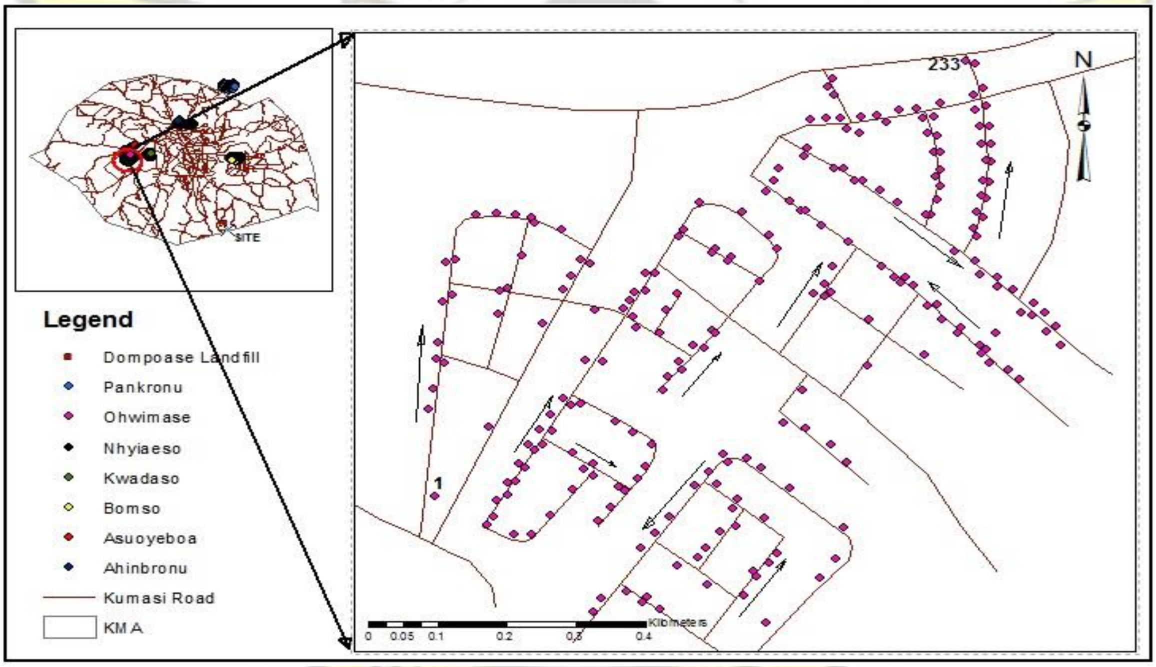

Figure 4.6: Company B House to house Collection -Ohwimase

Company C House to House Collection Service

House to house Collection of solid waste service took place at Tafo Nhyaeso and Tafo Pankrono communities. A total of 798 houses were served in both communities (413 houses in Tafo-Nhyaeso and 385 houses in Tafo-Pankrono) and a total of 502 stops (182 stops in Tafo Nhyaeso and 320 stops inTafo Pankrono) were made during the period of field monitoring. As company B, this also implied that 2 household bins were picked averagely per stop during the data collection. The number of households served and the number of trips made influenced the quantity of solid waste collected and disposed of, thus efficient (Figures 4.7, 4.8 and Table 4.3).

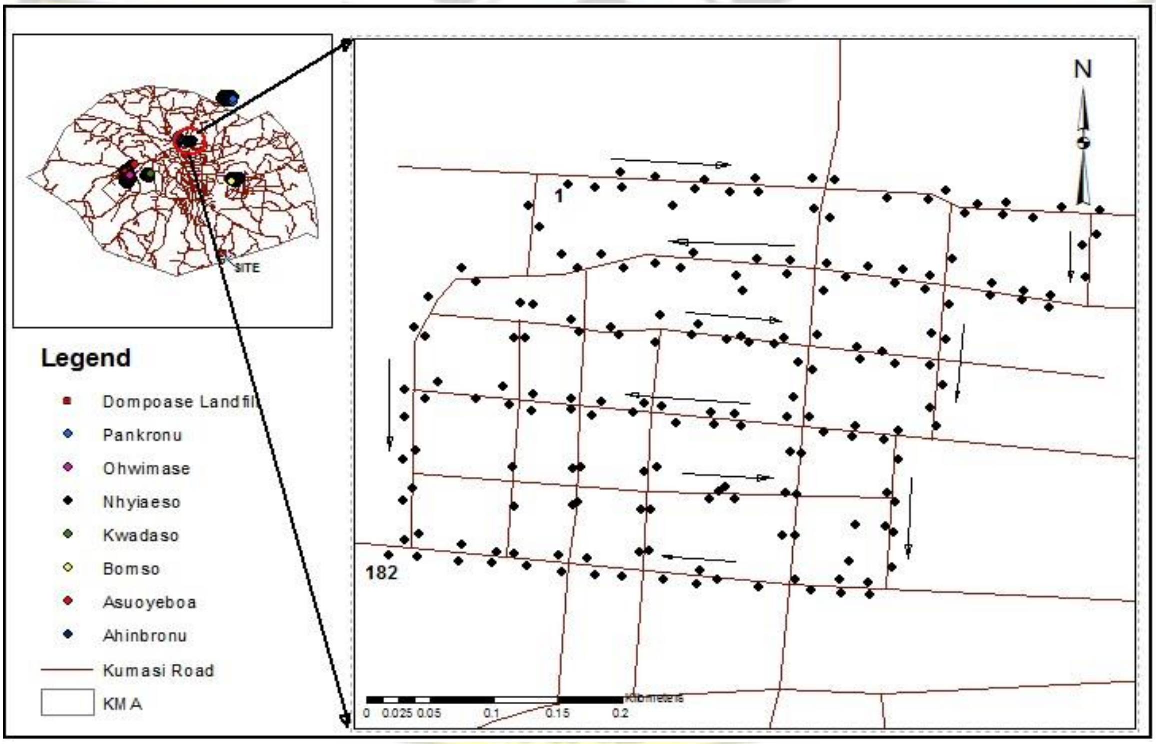

Figure 4.7: Company C House to house Collection -Tafo Nhyaeso

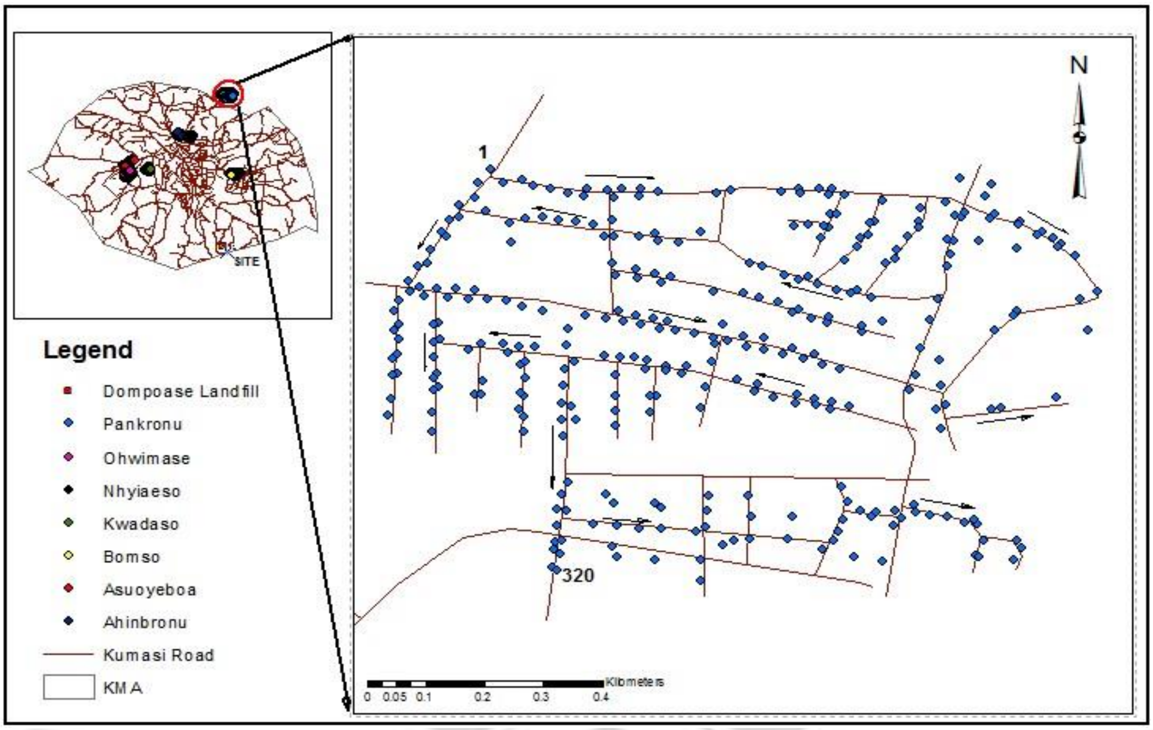

Figure 4.8: Company C House to house Collection – Tafo Pankrono

Arrows shown in the figures above indicated the defined routes that were taken by trucks while the points on the maps represented the number of stops made during house to house waste collection operations that ensured operational efficiency. The distribution of houses and skip containers influenced the travel time from one house to the other as well as from one communal skip container to the other in all selected operational zones. The average pickup times (mins) per household bin picked showed that Company A spent the least time to pick one bin while Company C spent the highest time to perform the same task (Table 4.3). Houses in Tafo-Pankrono were more closely located as compared to the other surveyed communities.

All selected companies used one compactor truck each within a community during daily house to house collection operations. Company B had collected the highest total number of 120 liter household bins during the collection period (821) but it collected 137 bins per trip day whiles Company C collected the total of Companies B and A collected a total of 798 and 358 120 liter bins each during the period of waste collection and collected 119 and 160 household bins (120 liter) per trip/day respectively.This indicated that Company C collected the highest number of household bins per trip on the daily basis and Company A collected the least quantity of household bins both in total during collection period and per trip per day. The reason why Company C collected the highest number of household bins per trip per might have been due to the better condition of its vehicle. All conditions being equal, Company A trucks performed relatively poor in terms of quantity (tonnage) of waste picked and number of customers served. Company C did far better followed by Company B with respect to quantity of waste picked and number of customers served per trip day during house to house collection service, thus Company C rated efficient. Generally, more household bins picked per trip per day indicated high pickup time and high quantity of solid waste collected which implied efficiency (Table 4.3).

Table 4.3 Summary of House to House monitoring activity

COMPANY:	**Company A**		**Company B**		**Company C**	
COMMUNITY:	**Bomso**	**Asuoyeboa**	**Kwadaso**	**Ohwimase**	**Tafo Nhyaeso**	**Tafo Pankrono**
No. of 120l Bins	213	145	497	324	413	385
No of stops	199	143	223	233	182	320

No of Bins/stop	1	1	2	1	2	1
Compactor Trucks	1	1	1	1	1	1
Haul Time(mins) Trip	41		26		96	
Total Pickup Time (mins)/Day	100		176		207	
Tonnes/Truck/Day	4		5		6	
Bins (120 Liter) Picked/Truck/Day	119		137		160	
Ave.Pickup Time (mins/bin)	1.26		1.28		1.29	
Ave. Round Trip Time (mins)/Trip/day	141		202		303	

Mapping of house to house household bins in the selected operational zones indicated that house to house bins were spatially distributed; none of the operational zones had a clumped distribution of customers. Solid waste collection maps in various operational zones furthermore helped in identifying the most defined efficient route (least time per kilometer) to be selected for solid waste collection which would influence haul and pick up times as well as haul distance of collection activities by the solid waste collection companies.

Additionally, the round trip times of the three waste collection companies were determined for both communal and house to house collection services. Results showed that the minimum and maximum round trip times for communal service were 51 and 57 minutes per trip respectively while the minimum and maximum round trip times for house to house were 141 minutes and the maximum of 301 minutes per trip respectively (Table 4.3). It was indicated that Company C spent the highest round trip time per trip for both communal and house to house services which trend was in agreement with its location from the landfill (Tables 4.2 and4.3).

4.3 Time and Trip Efficiency

Efficiency of solid waste collection that was monitored during the study focused on waste collected (tonnes), pick up time and haul time of selected waste collection companies in their respective selected operational zones in the Kumasi metropolis for both house to house and communal collection services. The average daily trips made by the three waste collection companies for both communal and house to house collection services were determined (Table 4.4).

Table 4.4 Average number of daily trips for solid waste collection

	Average Daily Trip/Truck	
Company	Communal Collection	House to House Collection
Company A	3	1
Company B	5	1
Company C	3	1

The study showed that Company B almost made as twice as the number of trips made by Companies A and C respectively. This meant that Company B was almost as twice as efficient compared to Company A and C (Table 4.4). This result could be due to the fact that company B had a lot of communal customers and a larger coverage area in its operational zone as compared to Companies A and C. Whiles the number of trips from the landfill records agreed with what the study found out for house to house solid waste collection during the monitoring activities, that of the communal collection did not agree with monitoring results of this study. This could be due to the fact that the overall number of communal trips (11) made per day during the monitoring was higher than the total number of communal trips (10) made per day from the landfill records by the three companies. It was observed that the number of trips made and number of customers served were directly proportional to the quantity of solid waste collected and disposed.

4.3.1 Waste Quantity (Tonnes) Collected (Selected Operational Zones)

Total quantity of waste collected during survey was also analyzed for both house to house and communal collection services in all selected operational zones for various selected companies (Figure 4.9).

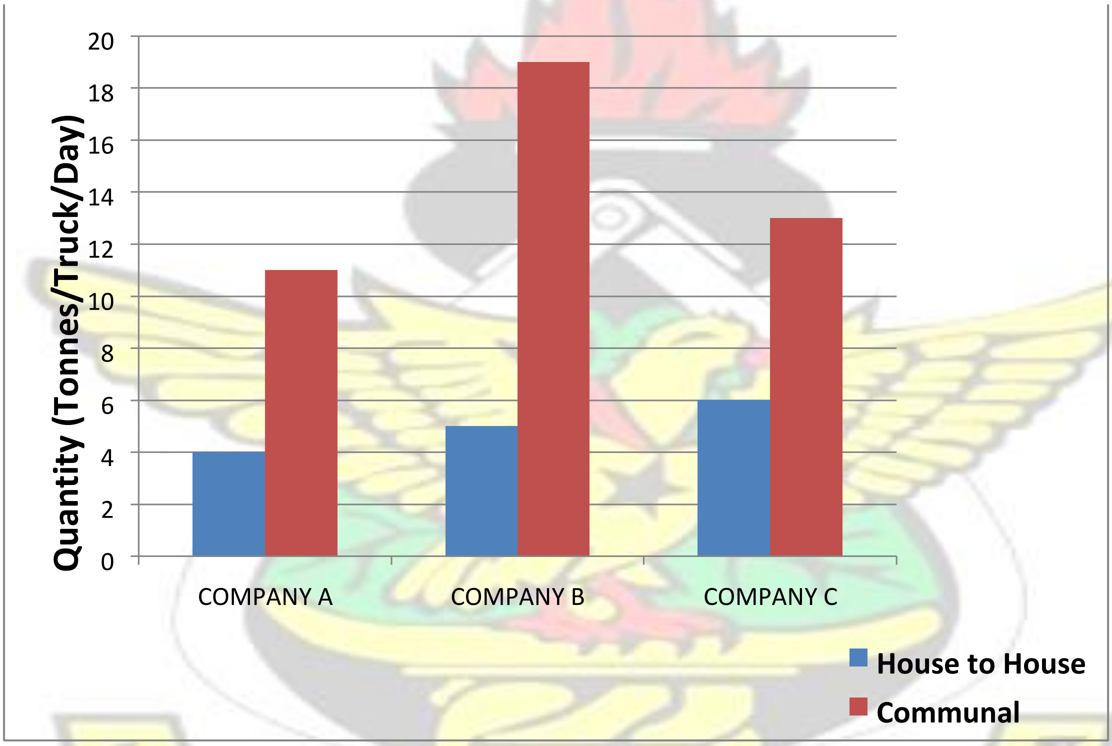

Figure 4.9: Quantity of Waste Collected by the Waste collection Companies During Field Monitoring

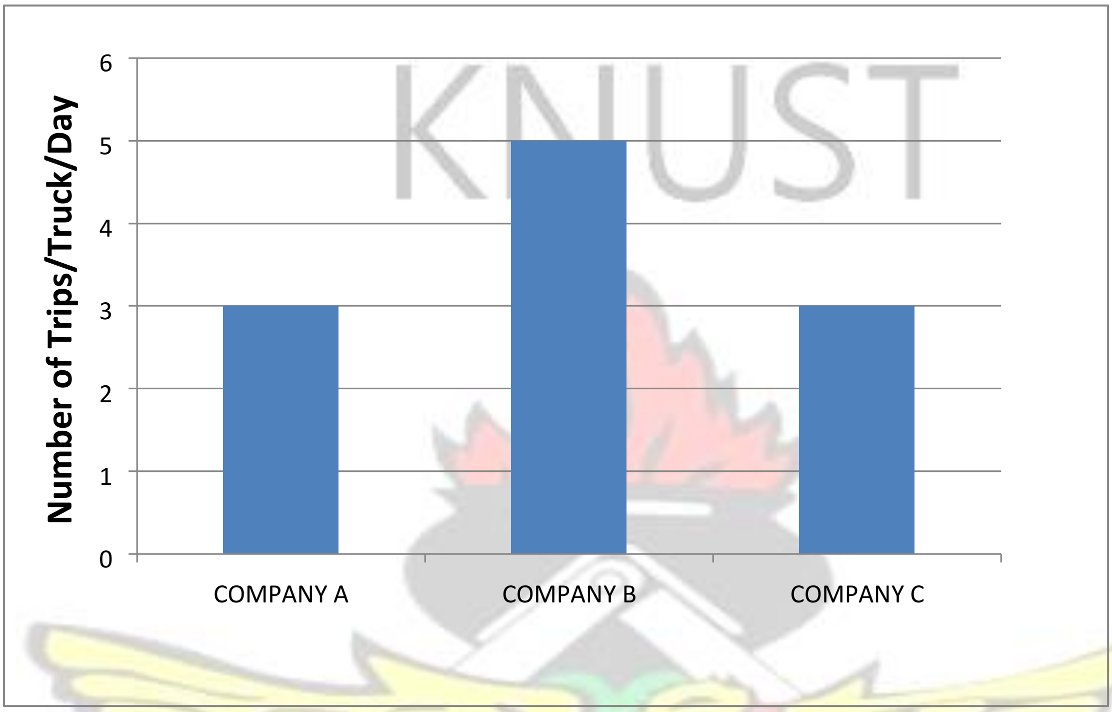

Figure 4.10: Communal Number of Trips Made per Truck per day by the Waste Collection Companies during Field Monitoring

Results (Figure 4.9) indicated that total waste collected for communal service was greater than that collected for house to house service within the period of data collection. This was due to the fact that communal collection service made more trips per day while house to house collection service made only one trip per day. It was therefore indicated that number of trips for communal collection service was directly proportional to the quantity of waste collected and disposed. Thus for communal collection service, Company B had the highest quantity of waste collected because it made the highest number of trips per day within the selected operational zone as compared to Company

C and Company A. More so, Company C had collected the highest amount of waste for house to house service per day (Figure 4.9). This was due to the fact that most of the houses that were served on the daily collection routine had bigger waste bins as compared to the houses served by Company B and Company A.

Further analysis that scaled down all household bins used by house to house to a 120 liter household bin indicated that a total of 821 (120liter) bins, 798 (120liters) and 358 (120liter) bins were collected by Company B, Company C and Company A respectively during the data collection period for this study. However, Company C collected 160 (120liter) bins per trip per day, which served as the highest quantity of waste collected per trip per day for house to house collection service. This trend also indicated that the number of household bins collected per trip per day for house to house collection service was directly proportional to the quantity of waste collected per day.

According to the above results obtained during monitoring, approximately, a total of 58 tonnes per day of solid waste was collected by the three waste companies with 43 tonnes and 15 tonnes per day collected by communal service and house to house service respectively, which represented 73.42% of what was collected previously as per the landfill records. This further indicated that general operation of the three companies was 73.42% efficient as related to the quantity of solid waste collected and disposed at the landfill.

4.3.2 Pickup Time

Data collection forms were developed and used to monitor the time spent during collection of solid waste from communal sites by the three waste collection companies. Pickup times for each of the three companies per communal trip and house to house trip were calculated (Main unit operations, Page 29 and Equation on page 46).

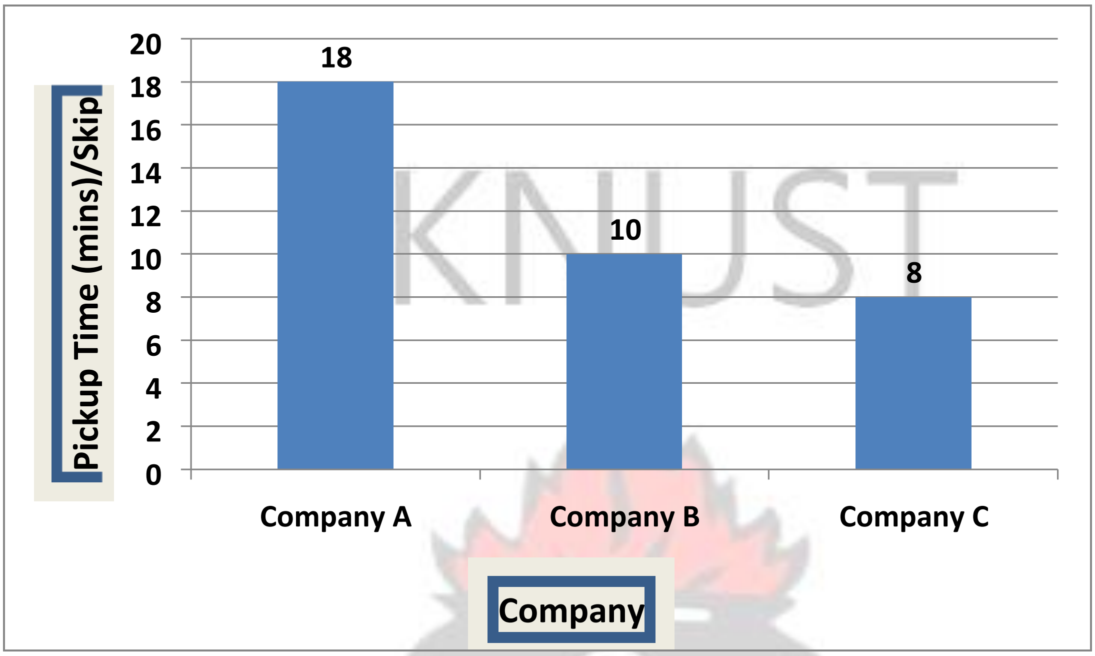

Figure 4.11: Communal Average Picktime (mins)/Skip/Day by the Waste Collection Companies during Field Monitoring

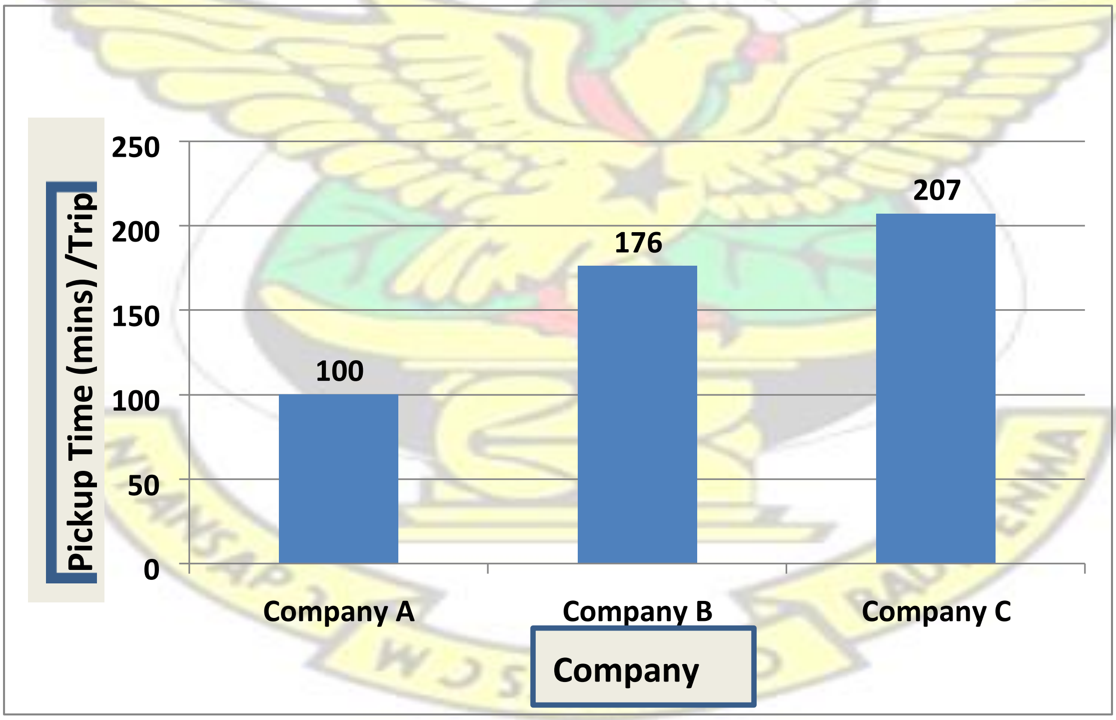

Figure 4.12: Mean House-to-House Pickup Time (mins)/Trip/Day during Field Monitoring

Results revealed that Company A spent the highest pickup time for communal collection service while its haul distance (km/trip/truck/day) was calculated to be 16 (Table 4.2 and Figure 4.12). The high pick up time of this company was mainly due to old age and poor maintenance facilities and practice of its operational vehicles. Company C on the other hand spent the least pickup time for communal solid waste collection service (Figure 4.11). This could be due to the fact that Company C had better operational vehicles in terms of age and better maintenance facilities and practice.

Pick up times for house to house collection for the three companies were found to follow opposite pattern as compared to that of communal collection service. Company A used the least total pickup time per trip per day for house to house collection service. Also Company C used the highest amount of pickup time for house to house collection service. This trend could probably be due to the fact that Company C collected the highest number of household bins per day and it had larger coverage area whiles Company A Solid Waste Collection Company served the least number of houses per day and it had less average operational coverage area with respect to house to house solid waste collection service. The minimum and maximum house to house pickup times (minutes) per trip per day were therefore picked determined to be 100 and 207 respectively (Table 4.3).

The average house to house pickup times (minutes) per household bin were calculated to be 1.26, 1.28 and 1.29 for Companies A, B and C respectively (Table 4.3). Although Company C spent the highest pickup time per bin, the differences among the three companies were not too significant.

4.3.3 Haul Time

Communal haul time for Company A was the least (34 minutes) among the three companies. This could probably be due to how close the selected operational zone is to the final disposal site. However, the number of trips made by Company A was the least compared to Company C and Company B. This might be due to poor vehicle and maintenance conditions. Company C on the other hand spent the highest haul time (49mins), which could probably be due to how far its operational zone is from the final disposal site. That, notwithstanding, Company C averagely made the same number of trips (3 communal trips/day) as Company A on the daily basis as was observed during data collection.

Haul time for house to house collection service for Company B was the least as compared to Company C and Company A. Average haul time by Company B was 26 minutes per house to house trip in a day whiles Company C used 96 minutes (Figure 4.13). This could be related to the difference in distances travelled from separate operational zones to the final disposal site. Company B travelled from Kwadaso to Dompoase and Company C travelled from Tafo to Dompoase. Another reason why Company C used 96 minutes on the average for one house to house trip could be due to the number of houses that was served and average coverage area of its zone of operation. Company C served 798 houses whiles Company B served 821 houses within selected operational zones during the monitoring period. Haul time was determined to be time spent from the last pickup point to the Dompoase landfill and back to the parking lot since only one trip was made per day, with the exception of time spent at the landfill to dispose the waste.

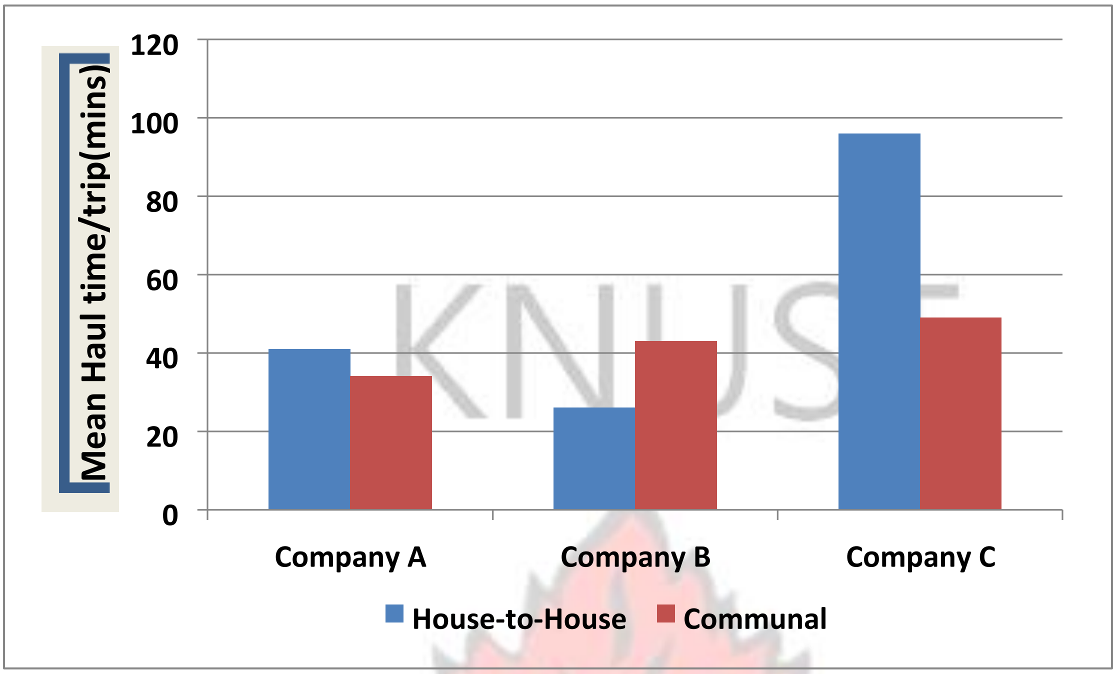

Figure 4.13: Mean Haul Time/trip/truck/day for Waste Companies

4.3.4 Operational Efficiency

Overall operational efficiency was analyzed using the framework mentioned in section 3.4, Figures 4.14 and 4.15 which indicated how efficient the operational activities of selected solid waste collection companies in selected operational zones were carried out for house to house and communal collection services respectively.

Increasing number of bins →

Increasing pickup time ↓

	Low Efficiency	**High Efficiency**
Low pickup time		Company C Pickup time low and also had highest number of household bins picked per trip per day.
High pickup time	Companies A and B Pickup times were high with a low number of household bins picked per trip per day.	

Figure 4.14: Comparison of operational efficiency (House to House)

Increasing number of skips →

Increasing round trip time ↓

Low Efficiency	**High Efficiency**
	Company B: Round trip time low and also had highest number of skips picked per trip per day
Companies A and C: High round trip time with low number of skips collected	

Figure4.15: Comparison of operational efficiency (Communal Collection) Round trip time was influenced by both haul time per trip and pickup time per household bin or per communal skip container picked during the solid waste

collection services.

Results (Figure 4.14 and 4.15) using the developed framework revealed that operations carried out by Company B were highly efficient for communal collection service and Company C was highly efficient for house to house collection service. This was due to the availability of good roads in the house to house operational zone of Company C and the number of skip containers that were available in the operational zone for company B. Additionally the large average coverage operational areas of Companies B and C influenced their efficiencies. Company A on the other hand was less efficient for both communal and house to house collection services.

This might be due to the fact that most of their trucks were not properly maintained.

4.4 Trend in the Number of Trips from Landfill Records

Total average number of trips for each of the selected waste collection companies for a period of twelve months was obtained from the final disposal site. This was then divided by the number of operational trucks for each company to get the number of trip for a truck for the period of twelve months (Figure 4.16).

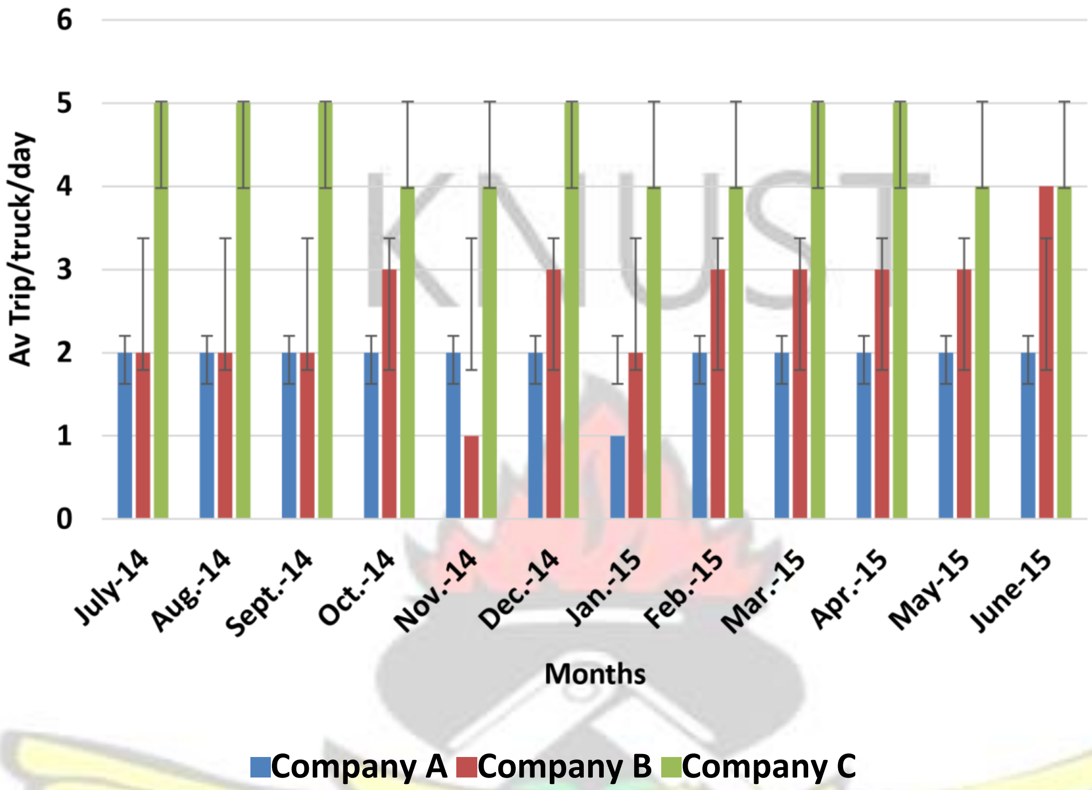

Figure 4.16: Number of Trips/Truck/Day for Selected Waste Collection Companies from landfill records

Data Source: KMA Waste Management Department (2015)

This study showed that Company C made the highest number of trips (5) per truck per day from July 2014 to June 2015. On the average Company C made approximately three times the trips made by Company A and two times the trips made by Company B. Number of trips for all companies however reduced (significantly for Company C and Company B) in November 2014 and January 2015 and increased in December 2014 (Figure 4.16). This might be due to the reason that families were cutting down on expenses and saving for the Christmas season, hence expenses increased during the Christmas season in December which probably led to an increase in number of trips in December. For the reduction in number of trips in January 2015, this could be due to the fact that most families had cut down on expenditure because of the expenses made during the Christmas season in December. An average of 4 trips was made in a day by the informal waste collection services as indicated by Agyem (2011).

4.4.1 Total Waste Collected from all Operational Zones (Landfill)

Total tonnage of waste for each of the selected waste collection companies for a period of twelve months was also obtained from the final disposal site at Dompoase in the Kumasi Metropolis. This was then divided by the number of operational trucks for each company to get the waste disposed of by a truck for the period of twelve months (Figure 4.17).

It was however observed that the weighbridge at the Dompoase Landfill had been out of operation over period of one year due to mechanical problem. This made it very difficult to get the actual measurement of the quantity of solid waste disposed of on the daily basis, hence the capacities of skip and compactor trucks were used to calculate the quantity of solid waste collected and disposed by the three solid waste collection companies.

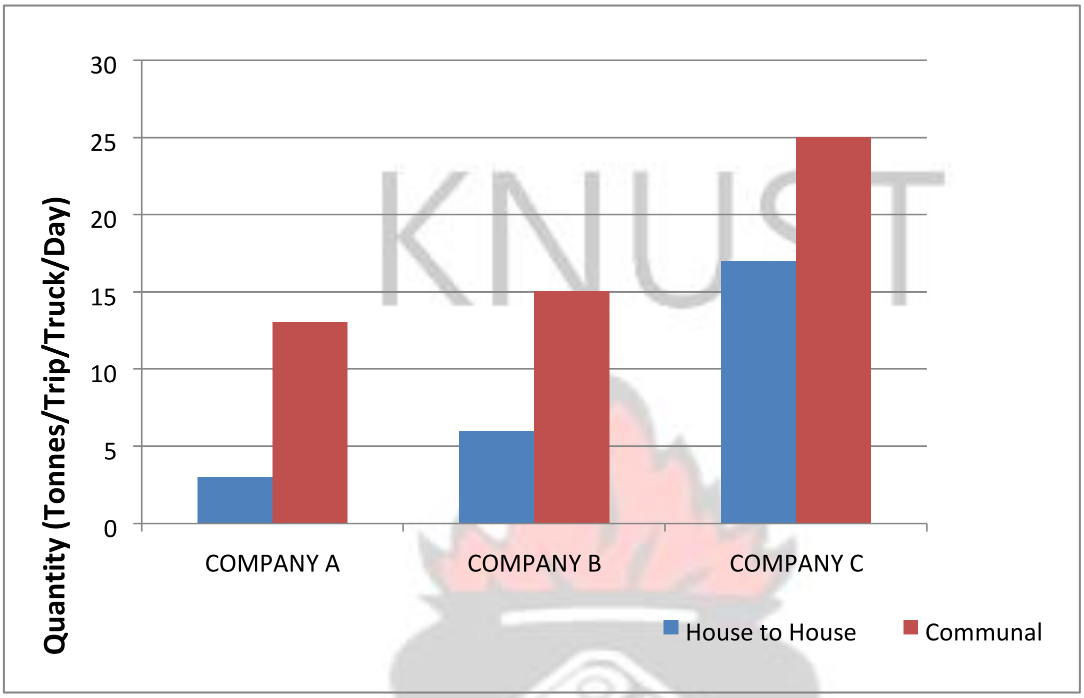

Figure 4.17: Waste (Tonnes)/Trip/Truck/Day for Selected Waste Collection Companies

Data Source: KMA Waste Management Department (2015)

The study showed that Company C had the highest quantity of waste (tons) disposed at the landfill per truck per day. Comparatively Company A made the least number of trips and Company C made the highest number of trips for communal collection service and this trend was followed by the quantity of waste collected and disposed during the monitoring period. This indicated that the number of trips made was directly proportional to the quantity of waste collected and disposed during the communal collection service. Approximately, a total of 79 tonnes per day of solid waste was collected and disposed of by the three solid waste collection companies as per the analysis of the landfill records obtained during the period indicated herein. This figure comprised of 26 tonnes for house to house collection service and 53 tonnes of communal collection service.

4.5 Cost Efficiency

Efficiency of collection services was analyzed from data obtained from the field survey. Analysis for cost of communal collection and cost of house to house collection services was based on staff per truck within the selected operational zone. Factors that were identified to have a high possibility of influencing cost of collection for both communal and house to house collection were the distances between collection points and the number of communal skip containers and house to house bins collected. Cost of collection crew was found to be the same for both types of services.

4.5.1 Communal Collection Cost Efficiency

Indicators that were considered for analyzing staff cost of communal collection service included mean number of communal trips per day, daily wage per driver and laborer, cost per trip for driver and laborer and the total cost per communal collection trip (Table 4.5).

Table 4.5. Operational and Maintenance (O&M) Cost of Communal Collection

Company	Mean trips/ day	Driver Cost/ day	Laborer Cost/day	Fuel cost /day	Maintenance cost/day	Total Cost /day	Cost/ trip/ day	Cost/ tonne /day
Company A	3	20	18	123	46	207	69	5
Company B	5	32	17	96	38	183	37	3
Company C	3	19	13	73	69	174	58	7

NB: All Cost in Ghana Cedi (GHC)

Less number of trips made as well as less number of skip containers picked indicated less quantity of waste collected, hence more cost incurred. The cost of maintenance for Company A (GHC 46.00) was however low and that could have affected the number of trips made in the day, since regular maintenance of vehicle could affect the level of collection efficiency. Cost per communal trip and cost per tonnage of waste collected for Company B on the other hand were the least as compared to the other selected companies (Company C and Company A), however Company B made the highest number of communal trips in a day. Total cost for communal collection in a day was highest for Company A (GHC 207.00), and that for Company B was lower (GHC 183.00) (Table 4.5). As indicated in the results shown in table 4.5, Company B was cost efficient since it invested the least amount of money (GHC3/tonne of waste) per tonne of waste collected when compared with Companies A and C, which invested GHC 5 and GHC7 respectively per tonne of waste. However, a study carried out by Agyen (2011) indicated that within the Oforikrom operational zone (Company A) average number of communal trips in a day was 1 whiles cost per trip was GHC 12.00. This indicates an increase of 2 trips in communal collection efficiency. Agyen (2011) also reported that communal number of trips per day in the Tafo operational zone (Company C) was 2 as opposed to 3 which were found by this study.

According to KMA, solid waste companies are supposed to charge between GHC 150 to GHC 200 per trip for communal solid waste collection. Hence for Company A if the cost incurred in a day is GHC 207 for all 3 trips this means that Company A could make an income ranging from GHC 450 to GHC 600 for a day. Therefore company A could make a profit range of GHC 243 to GHC 393 daily for communal solid waste collection. This was because company A made an average of 3 trips in a day. Company B also spent GHC 183, could make an income ranging between GHC 450 to GHC 600, hence a profit margin between GHC267 and GHC 417, since it made an average of 5 trips in a day. Company C also made a profit between GHC 276 and GHC 426 on a daily basis, taking into consideration total cost per day (GHC 174) and average number of trips (3).

4.5.2 House to House Collection Cost Efficiency

Indicators that were considered for analyzing cost of house to house collection service included cost of driver and laborer for a day, cost of fuel used for collection in a day and the cost of daily maintenance of compactor trucks, cost per collection trip (derived by dividing the total cost per day by the number of trips in a day) and cost per ton of waste collected (derived by dividing the total cost per day by the total tonnage of waste collected). All three companies had three laborers and one driver for house to house collection services (Table 4.6).

Table 4.6 (O&M) Cost of House to House collection

Company	Number of Bins(120l) picked/day	No. of trips/ day	Driver Cost/ day	Laborer Cost/ day	Fuel cost/ day	Maintenance cost/ day	Cost /day	Cost /tonne/ day
Company A	119 (4 ton)	1	20	18	190	52	280	70
Company B	137 (5 ton)	1	32	17	125	48	222	44
Company C	160 (6ton)	1	19	13	73	69	174	29

NB: All Cost in Ghana Cedi (GHC)

Total cost of collection for Company A was the highest thus, GHC 280.00. This was influenced mainly by the cost of fuel for collection in a day which was more than two times the fuel used by Company C in a day. Furthermore cost per tonne of waste was highest for Company A (GHC 47.00) as compared with Company C and Company B even though Company A collected the least number of waste bins and stops. Hence Company A was not efficient whiles Company C was efficient in terms of cost for house to house services. Total cost of collection for house to house service was least for Company C (GHC 174.00) and least cost per tonne (GHC 18.00). This could

probably be due to the fact that it picked the highest number of household bins and the cost for driver, laborer and fuel used per day was least. Company C, however, spent the highest amount on maintenance per truck per day within the selected operational zone for house to house collection.

4.6 Service Quality

4.6.1 Customer Satisfaction of Communal Collection Services

Communal service customers within all the collection zones were interviewed on how satisfied they were with the service they received from their respective solid waste services providers (Figure 4.18). A total of 140 customers were interviewed in each zone of operation and 480 customers in all were interviewed from the three solid waste collection companies (Table 3.1).

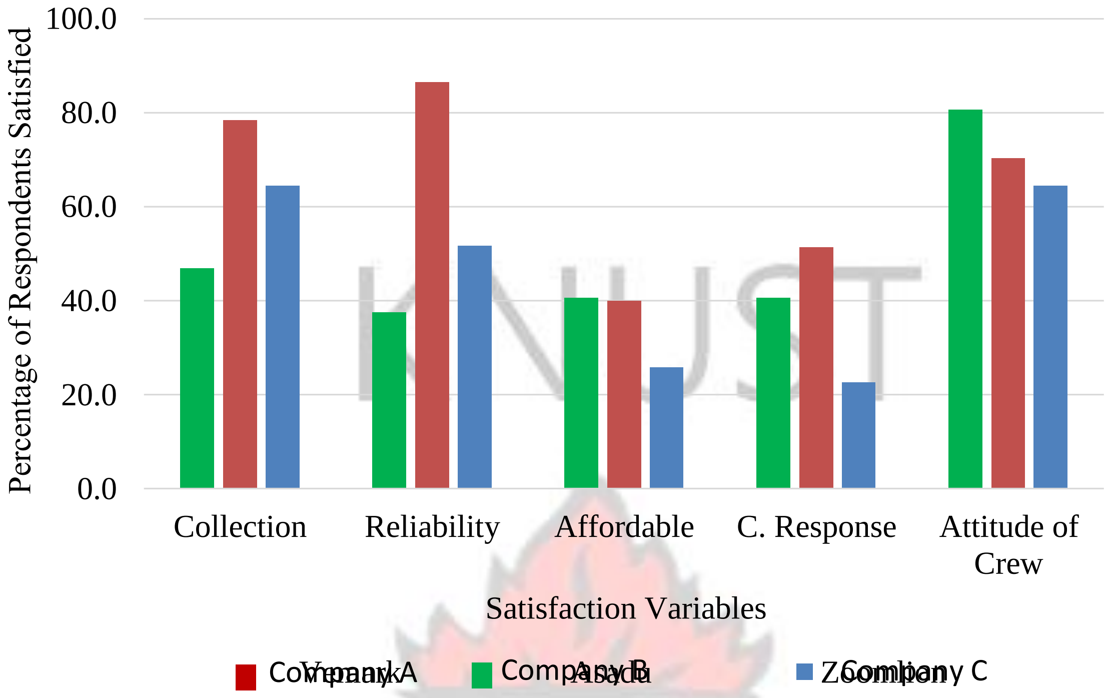

Figure 4.18: Percentage of respondents satisfied with communal collection Service

Results of the study showed that 53% and 63% of customers were not satisfied with the collection and collection reliability respectively. The study further indicated that on the average 36% of customers (of all 3 companies) that received communal collection services were satisfied with cost of service they received and 64% were dissatisfied with the amount they paid for service. Another satisfaction variable however, that a greater percentage of communal collection service customers were not satisfied with was how prompt service providers responded to complaints from customers. About 51%, 41% and 27% of customers of Companies A, B and C respectively were satisfied with how prompt service providers attended to complaints made.

Overall satisfaction of customers towards the services received from service providers was analyzed. It was determined that 73%, 77% and 87% of customers were satisfied with the overall service provided by Companies A, B and C respectively (Figure

4.19).

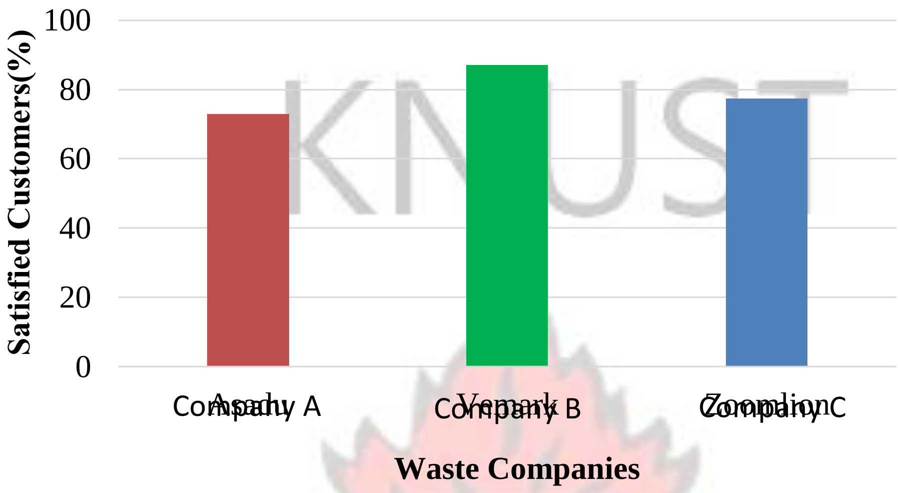

Figure 4.19: Customer Satisfaction (overall communal collection service)

Further analysis revealed that Company B had the least cost for collection crew per communal trip, but they had most (87%) of their customers satisfied with the overall service they received. Company A on the other hand had the highest cost for collection crew per communal trip but had the least (73%) when compared with the customers satisfied with the overall services provided by all three companies.

4.6.2 Customer Satisfaction House to House Collection Service

Customers of House to House collection services where interviewed to investigate whether they were satisfied with services received from respective service providers regarding collection frequency, reliability of collection, cost of collection, prompt response to complaints and the attitude of collection crew.

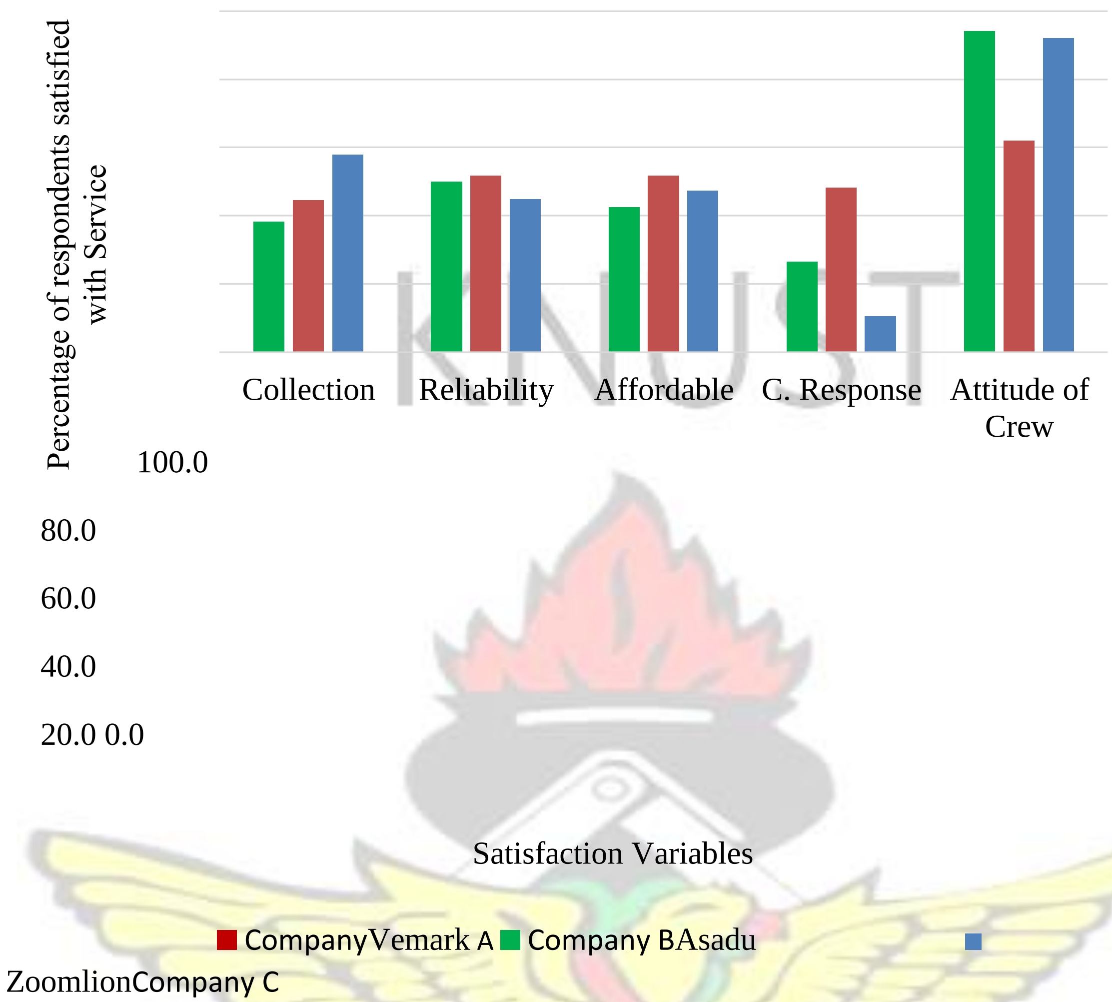

Figure 4.20: Customer Satisfaction (House to house collection)

Results of the study indicated that less than 50%, thus an average of 47%, 49%, 47% and 28% of house to house customers interviewed within the selected operational zone were satisfied with collection frequency, reliability of collection, cost of collection and the prompt response they received from service providers when complaints were made by customers respectively. However, an average of 83% of respondents across all selected operational zones were satisfied with attitude of house to house collection crew (Figure 4.20).

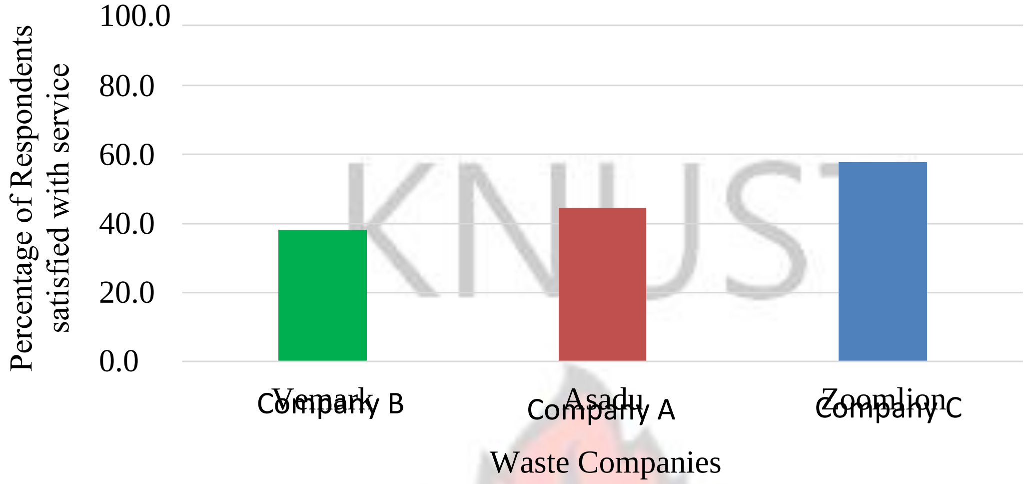

Figure 4.21: Customer Satisfaction (overall house to house collection)

Results of the study indicated that 38%, 44% and 57% of Company B, Company A and Company C customers were satisfied with the overall service delivery provided by their respective service providers. This could be probably be due to the fact that Company C had tricycle going to areas that were inaccessible by the skip truck for house to house collection, unlike other companies where customers had to walk to skip trucks in area that could not be accessed by the skip trucks, this most of the customers uncomfortable since they were paying for the service. Again results revealed that although Company C spent least for salary on collection crew (among other companies) for house to house collection services as indicated in Table 4.3, she had the highest number of customers satisfied with her overall service delivered (figure 4.18). Furthermore, Company B spent highest among three selected companies for house to house collection service but had the least percentage of customers being satisfied with the overall service provided.

The overall efficiency based on customer satisfaction levels were also analysed from individual customer‘s satisfaction levels from the various individual indicators that were used for assessing satisfaction. Satisfaction levels were ranked from low, through moderate to high (Table 4.7).

Table 4.7 Overall efficiency from Customer satisfaction

	Company A		**Company B**		**Company C**	
Collection Type	House to House	Communal Collection	House to House	Communal Collection	House to House	Communal Collection
Customer Satisfaction	Low	Low	Low	High	High	Low
Freq. of collection	2	2	2	2	2	2
Overflow	No	Yes	No	Yes	No	No
User Charge (GHC)	15	1	15	1	15	1
Round trip time (min)	190.0	44.4	198.1	46.8	303.0	58.0
O&M Cost/ trip (GHC)	280	69	222	37	174	58
Overall efficiency	Low	Low	Low	High	High	Low

Round trip time was influenced by the pickup and haul time of collection by solid waste companies. Round trip time was highest for house to house collection servicefor Company C because the highest number of household bins were collected by Company C. Also Company C travelled the furthest distance from operational zone to the final landfill site and this increased the haul time per trip hence the highest round trip time. Round trip time was minimal for Company A for both house to house and communal collection because they collected the least number of skips and house to house bin in a day during the monitoring activities. Moreover, distance from operational zone to the final landfill site was shortest as compared to operational site of Companies B and C.

Frequency of collection in study area was well structured for house to house services as compared to communal collection services. House to house collection services were done at most twice a week. Communal collection was predominantly carried out by service providers as and when they were called by communal site caretakers. This resulted in some of the communal skips overflowing with waste at some of the communal sites (Plates 4.1 and 4.2).

Plate 4.1 Overflow skip at Company B communal site

Plate 4.2 Overflow skip container at Company A communal site

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

For this study it can be concluded that

- The distribution of both communal skips and house to house bins in an operational zone influenced resources, hence the efficiency of collection.
- Mapping helped to identify and determine pick distances between pickup points as well as haul distances for house to house and communal collection services.
- Total quantity of solid waste collected and disposed by the three waste companies during monitoring was 58 tonnes per day and that which was earlier collected by the same three companies was 79 tonnes per day as obtained from the landfill records. Therefore the three companies were 73.42% efficient of waste previously collected and deposited at the landfill per day by the same companies.
- Minimum and maximum pickup times (minutes) per skip container for communal collection service were determined to be 8 and 18 respectively while the minimum and maximum house to house pickup times (minutes) per household bin were calculated to be 1.26 and 1.29 as well as 100 and 207 minutes per trip respectively.
- Companies which collected higher number of household bins and skip containers at low pickup time per day were efficient. Hence, Company B was efficient in communal collection service while Company C was efficient in house to house

collection service. Company A was not efficient in any of the two types of services because it did meet the target of efficiency for any of the services.

- Companies which served higher number of customers were found to operate at minimum cost, thus indicated to be efficient with respect to cost.
- Cost of collection for house to house service was calculated to be higher than that for communal collection service.
- More customers were satisfied with services of companies which operated at minimum cost.

5.2 Recommendations

- Further studies should be carried out in other operational zones of the selected solid waste collected companies within Kumasi Metropolis to find out if collection efficiency and cost efficiency will be the same as established by this study.
- Waste Management Department of Kumasi Metropolitan Assembly should carry out periodic field visit to communal sites to serve as a check for both solid waste collection companies and communal site care takers.
- The solid waste collection companies should be encouraged to increase the quantity of solid waste to be collected and disposed at the landfill.
- The weighbridge at the landfill to be repaired or replaced for accurate measurement of solid waste being disposed.
- Customers of both communal and house to house solid waste collection services need to be educated on domestic management of solid waste.
- Capacity of communal site caretakers need to be improved to ensure the proper management of the communal sites for the communal skip containers.

- The project for the construction of sheds with concrete floors at the various communal skip sites should be continued so as to avoid leachate from seeping into the soils during rains.

REFERENCES

Abankwa V., Grimard A., Somer K. and Kuria F. (2009). United Nations Human Settlements Programme (UN-HABITAT). www.unhabitat.org/pmss /get Electronic Version.aspx?nr=2929. Accessed; 23th March, 2011.

Achankeng, E. (2003) ―Globalization, urbanization and municipal solid waste management in Africa,‖ African Studies Association of Australasia and the Pacific 2003 Conference Proceedings—African on a Global Stage, University of Adelaide, Adelaide, Australia.

Adu-Boahen, A. (1965). Topics in West African History, Longman, London; 66p.

Afonso, A., Schuknecht, L., and Tanzi, V. (2005). Public sector efficiency: An international comparison. Public choice, *123*(3–4), 321–347.

Awortwi, N., 2004. Getting the fundamentals wrong: Woes of public-private partnerships in solid waste collection in three Ghanaian cities. *Public Administration & Development*, *24*(3), p.213.

Babanawo, R. (2006). Constraints to Sustainable Solid Waste Management in Ghana. PhD Dissertation Submitted at the Brandenburg University of Technology, Cottbus, Germany

Bartone, C.R. (1999). Financing solid waste management projects in developing countries: Lessons from a decade of World Bank lending, in proceedings of organic recovery and biological treatment, ORBIT 99, Part 3, Rhombus, Berlin, pp. 757-765

Beede, D. N. and Bloom, D. E. (1995). Economics of the Generation and Management of Municipal Solid Waste. National Bureau of Economic Research (NBER), Cambridge, MA, USA, Working Paper No. 5116.

Callan, Scott J. and Janet M. Thomas (2001), ―Economies of scale and scope: A cost analysis of municipal solid waste services,‖ *Land Economics*, 77 (3), 548-560.

Centre for Environment and Development (2003). Study of the Attitude and Perception of Community towards Solid Waste Management. A case study of Thiruvananthapuram city-Phase II. Submitted to Kerala Research Programme on Local Level Development.

Cointreau, S. J. (1982). Environmental Management of Urban Solid Wastes in Developing Countries: A Project Guide, The World Bank, Washington, DC, USA, 1st edition.

Cointreau-Levine S. (1994). Private Sector Participation in Municipal Solid Waste Management, Urban Management Programme Paper No 13, World Bank, http://www.developmentbookshop.com/detail-aspx?ID=1039, (accessed 2006 February 28).

Cointreau-Levine, and Adrian Coad (2000) Guidance Pack: ―Private Sector Participation in Municipal Solid Waste Management, http://www.sanicon.net /titles/title.php3?titleno=472, (accessed February 28, 2015).

Dijkgraaf, Elbert and R.H.J.M. Gradus (2003), ―Cost savings of contracting out refuse collection,‖ *Empirica*, 30 (2), 149-161.

EGSSAA, (2009).Environmental Guidelines for Small-Scale Activities in Africa.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society*. *Series A (General), 120*(3), 253–290.

GEPA, Environmental Protection Agency (2002). Ghana‘s State of the Environment Report EPA, MES, MLGRD, (2002) Ghana Landfill Guidelines: Best Practice Environmental Guidelines. Accra, Ghana.

Gershman, B., 1986. Small-scale municipal solid waste energy recovery systems. Van Nostrand Reinhold, Cia.

Kemper, P. and John Quigley, 1976. The economics of Refuse Collection. Cambridge (MA): Ballinger; pp. 19-21

Ketibuah, E., Asase, M., Yusif, S., Mensah, M.Y., and Fisher, K. (2010). Comparative analysis of household waste in the cities of Stuttgart and Kumasi-Options for waste recycling and treatment in Kumasi. Institute for Sanitary Engineering, Stuttgart, Germany. Department of Chemical Engineering, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Kisner C. (2008). Green roofs for urban food security and environmental sustainability. Urban agriculture case study: Harare, Zimbabwe. Retrieved from: http://www.climate.org/topics/international-action/urban-agriculture/ har are. html. Accessed: 9 July, 2015.

Kontos, T.D., Komilis, D.P. and Halvadakis, C.P., 2005. Siting MSW landfills with a spatial multiple criteria analysis methodology. *Waste management*,*25*(8), pp.818-832.

Kreith, F. (1994). Handbook of Solid Waste Management. McGraw Hill, USA.

Kumah, A.M. (2007). The Situation of Solid Waste in Ghana. Accra, Ghana; pp.34-35

McDougall, F., White, P., Franke, M. and Hindle, P. (2001), ―Integrated Solid Waste Management: A Life Cycle Inventory‖, Blackwell Science, Oxford, UK, 18p.

McDougall, F.R., White, P.R., Franke, M. and Hindle, P., 2008. Integrated solid waste management: a life cycle inventory. John Wiley & Sons.

Mensah, A. and Larbi, E. (2005). Solid waste disposal in Ghan*a*. http://www .trend. wastsan.net. Accessed on 24th April, 2015.

Momoh, J.J. and Oladebeye, D.H., 2010. Assessment of awareness, attitude and willingness of people to participate in household solid waste recycling programme in Ado-Ekiti, Nigeria. *Journal of Applied Sciences in Environmental Sanitation*, *5*(1), pp.93-105.

Muniafu, M. and Otiato, E. (2007). Solid Waste Management in Nairobi, Kenya: A Case for Emerging Economies. *The Journal of Language, Technology & Entrepreneurship in Africa*, 2(1); 342-350.

Ogawa, H. (2005). Sustainable Solid Waste Management in Developing Countries, World Health Organization Western Pacific Regional Environmental Health Centre Kuala Lumpur, Malaysia. Presented on the 7th ISWA International Congress and Exhibition. http://www.gdrc.org/uem/waste/swm-fogawa1.htm Accessed; April, 2011

Richard L. T. and Woodbury B. P (1998). Municipal solid waste composting: strategies for separating contaminants.

Schubeller, P., Wehrle, K and Christen, J. (1996). Urban Management and Infrastructure. Conceptual Framework for Municipal Solid Waste Management in Low-Income Countries. Working Paper No. 9. UNDP/UNCHS (Habitat/World Bank/SDC Collaborative Programme on Municipal Solid Waste Management in Low-Income Countries. St, Gallen, SKAT.

Shafiul, A.A. and Mansoor, A. (2003). Partnerships for solid waste management in developing countries: Linking theories to realities in the Institute of Development Engineering, Water and Development Centre (WEDC). Loughborough University, U.K.

Tchobanoglous, G., H. and Eliason, R. (1977). Solid Waste: Engineering Principles and Management Issues. McGraw-Hill Publishing Company, USA; 477P.

Tchobanoglous G, Theisen H., and Vigil S.A. (1993). Integrated solid waste management Engineering Principles and Management Issues. New York: McGraw Hill Inc. 978p.

United Nations Environment Programme (UNEP) and International Environmental Technology Centre (IETC), (1996). International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management , Osaka, Japan/ www.unep.or.jp/ietc/ESTdir/Pub/MSW/index.asp

United Nations Environmental Programme (UNEP), (2009). Generation of Waste is Rapidly Increasing at a Global level. (website: http:/www.unep.org.jp/iect/ESTdir/Pub/CSWMS/index.asp).

United States Environmental Protection Agency (USEPA), (2011). Waste-Resource Conservation-Reduce/Reuse Recycle http://www.epa.gov/epawaste/ conserve /rrr/ reduce.htm Accessed; 12th April, 2015.

United States Postal Services (USPS), (2000). Solid Waste Management Plan for Thimphu City, Bhutan, Draft version, April 2000. Bhutan: Urban Sector Programme Support Secretariat pp. 44-46

Wullt, J. (2010). 40% of Municipality Waste Recycled or Composted in 2008. Eurostat Press Office, Luxembourg Retrieved from: http://ec. europa. eu/ eurostat, Accessed: June 18, 2015.

Zerbock, O. (2003). Urban Solid Waste Management: Waste Reduction in Developing Nations. (www.cee.mtu.edu). Accessed on 18th May, 2015

APPENDICES

Appendix A- Questionnaire for House to House Survey

Questionnaire for Household Satisfaction Levels for Solid Waste Collection Services in Kumasi Metropolis

(MSc. Water Supply and Environmental Sanitation, Civil Engineering Dept-KNUST)

A. Identification

Sub Metro		**Date of interview**	

B. Respondent Basic Information

Q1. Age ☐ Q2. Gender ☐

Q3. Education

Did not attend school	1
Primary school	2
Secondary/Technical NOT completed	3
Secondary/Technical completed	4
Post-Secondary	5
Other Specify...	6

C. HOUSEHOLD DETAILS

Q4.Household size ☐

Q5. Residential Tenure Status

Owner-Occupant	1
Tenant	2
Rent Free Occupant	3
Other……………………………………	4

D.SOLID WASTE COLLECTION SERVICE

Q7. Solid Waste Collection Used

Door to Door/Kerb Side	1
Communal Bin	2
Other………………………………..	3

Q8. Frequency of collection

Once a week	1
Twice a week	2
Monthly	3
Other…………………………………	4

Q9. Mode of Payment

Pay as you throw/when collected	1
Weekly	2
Monthly	3
Yearly	4

Q10.Cost of collection/Dumping (GHC)

Q11. Average Distance to Communal bin (metres)

Within 100m	1
100-200m	2
200-300m	3
Above 300m	4

Q12. Average Travel Time to bin (Return)

Within 5mins	1
5-15mins	2
15-45mins	3
More than 45mins	4

Q13. Average Time Spent at Communal Bin

Within 5mins	1
5-10mins	2
10-20mins	3
More than 20mins	4

E. GENERAL HOUSEHOLD SATISFACTION LEVELS WITH SOLID

WASTE COLLECTION SERVICES

To what extent are you satisfied with the following services rendered by your waste collection service provider	Very Dissatisfied	Not Satisfied	Not Sure	Satisfied	Very Satisfied
Frequency of waste collection from household					
Reliability of waste collection					
Prompt response to user complains					
Vehicles and equipment used to collect and dispose waste					
Handling of waste containers during transportation					
Cost of Service					
Cleanliness of service area					
Public monitoring and sanctioning by Municipal Assembly					
Behaviour/attitude of collection crew towards residents					
Household education on waste management					
Neatness of waste collection crew, wearing of protective clothing					
Overall service delivery					

Appendix B- Questionnaire for Solid Waste Collection Companies

Assessment of Efficiency of Solid Waste Collection Services in the

Kumasi Metropolis

(MSc Water Supply and Environmental Sanitation-KNUST)

This questionnaire is designed to facilitate the assessment of the efficiency of the current solid waste collection services in Kumasi Metropolis. To enable an accurate assessment, it is important that all information requested in the questionnaire be provided as completely and accurately as possible. This data sheet is to be filled by the appropriate personnel in the Company.

NB: Data provided on this sheet would be treated with the highest level of confidentiality since it is for Academic Analytical Purpose only and would not be put in the public domain.

Confidential Measures

- Name of company should not be provided on the sheet
- Data sheet has not been coded

Declaration: I …………………………. will be responsible for the confidential treatment of information provided.

Date: ………………………………….. Signed…………………………

SECTION A: SOLID WASTE COLLECTION SERVICE

(Kindly fill where applicable, write "N/A", where not applicable or unknown)

Designation of Respondent [ ]

1. Type of service provided

Communal Collection	1
Door to Door Collection	2
Communal and Door to Door	3
Other…………………………………………..	4

2. Frequency of collection with operational zone(s) (Yes=1, No=2)

	Commercial Customers	**Door to Door**	**Communal Collection**
Daily			
Twice a weekly			
Once a week			
Every 2weeks			
Others……………			

3. No of staffs on a compactor truck per day (driver inclusive).

Compactor Truck	
Skip Truck	

4. Number of trucks on route on any collection day (Communal collection)

Compactor Truck(s)	
Skip Truck(s)	

5. Working hours spent during collection (departure from yard to return-hrs).

6. Do drivers work overtime during the weekends? (Yes/No)

7. How many hours do trucks work on weekends?

Saturday	
Sunday	

8. Required number of trips per truck/day.

Collection Type	Required No. of Trip(s)/truck/day
Commercial Collection	
Communal Collection	
Door to Door Collection	

9. Which of the following mode of tariff collection do you use? (Yes=1/ No=2)

	Commercial Area	Door to Door	Communal Collection
Pay as you throw			
Weekly collection			
Monthly collection			
Other……………			

10. How many commercial customers do you provide service to in your operational zones?

11. What is the charge (GHC) per bin/skip for different areas within your operational zones?

	Size of bin/Skip (Volume)	Amount Charged (GHC)
Commercial Collection		Charge/month/bin…………….
Door to Door collection		Charge/month/bin…………….
Communal Collection		Charge/lift…………………….

12. Total number of communal skips provided in operational area

Size of Skip (Volume)	Quantity provided

13. Total number of household bins provided in operational areas

Size of bin (Volume)	Quantity provided

14. Total number of commercial customer bins provided in operational area

Size of bin (Volume)	Quantity provided

15. Provide cost data on the following

PERSONNEL COSTS				
S/N	Item	Number	Rate(GHC)	Amnt/month (GHC)
1	Drivers(salaries and fringe benefits)			
2	Labour(salaries and fringe benefits)			

EQUIPMENT/MATERIAL COSTS							
S/N	Item	Qty	Make	Yr Acq.	Unit Cost	Useful Life Yrs	Total Cost(GHC)
1	Compactor truck						
2	Roll on truck						
3	Skip truck						
4	Pickup trucks						
5	Small cars						
6	Motorbikes/Tricycle						
7	Skip Containers						
8	Household Bins						

COLLECTION SERVICE		Quantity	Unit Cost	Total Cost
1	Fuel for compactor trucks			
2	Fuel for skip trucks			
3	Fuel for Roll-on trucks			
4	Fuel for pickups			

5	Fuel for small cars			
6	Maintenance & servicing of compactor			
7	Maintenance and servicing of roll-on trucks			
8	Maintenance and servicing of skip trucks			
9	Maintenance and servicing of pickups			
10	Maintenance and servicing of small cars			
11	Management & Administration Cost(Overhead)			
12	Plant & Equipment Hire(Type)			
13	Vehicle Availability (%)			
14	Insurance			
15	Miscellaneous (%)			