ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF GRADUATE STUDIES

GEODESY AND GEOMATICS ENGINEERING PROGRAM

GIS BASED ANALYSIS OF THE LOCATION OF COLLECTION BINS FOR MUNICIPAL SOLID WASTE MANAGEMENT SYSTEM IN ADAMA TOWN, ETHIOPIA

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SCIENCE IN GEODESY AND GEOMATICS ENGINEERING

By

DEREJE BEKELE GUDETA

MAY, 2015

ADAMA, ETHIOPIA

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DECLARATION

I hereby declare that the thesis entitled *GIS Based Analysis of the Location of Collection Bins for Municipal Solid Waste Management System in Adama Town*, Ethiopia has been carried out by me under the supervision of Dr. Messay Mulugeta and Daniel Alemayohu, Department of Environmental Geography and Geomatics Engineering, respectively, Adama Science and Technology University during the year 2013-2015 as a part of Master of Science program in Geodesy and Geomatics engineering degree and that to the best of my knowledge, it contains no materials previously published by another person nor materials which has been accepted for an award of any other degree of a university, except where due acknowledgement has been made in the text.

Name: Dereje Bekele

Place: Adama Science and Technology University, Ethiopia

Date of submission: May, 2015

Signiture:

CERTIFICATE

This is to certify that the thesis entitled *GIS Based Analysis of the Location of Collection Bins for Municipal Solid Waste Management System in Adama Town*, Ethiopia is real work carried out by Dereje Bekele under our guidance and supervision. This is the actual work done by Dereje Bekele for the partial fulfillment of the award of the Degree of Master of Science in Geodesy and Geomatics Engineering from Adama Science and Technology University, Adama.

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Dereje Bekele
May, 2015
Adama, Ethiopia

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Abbreviations and Acronyms

AMPRP:	Adama Master Plan Revision Project
CSA:	Central Statistics Authority
DN:	Demand Node
ESRI:	Environmental Sciences Research Institute
GIS:	Geographic Information System
GIT:	Geo information Technology
GPS:	Global Positioning System
MDG:	Millennium Development Goal
NUPI:	National Urban Planning Institute
MSE:	Micro and Small Enterprise
MSW:	Municipal Solid Waste
MSWM:	Municipal Solid Waste Management
NA:	Network Analyst
NEMA:	National Environmental Management Authority
NGOs:	Non-Governmental Organizations
RWG:	Rate of Waste Generated
SDB:	Spatial Data Base
SWC:	Solid Waste Container
SWM:	Solid Waste Management
SWMS:	Solid Waste Management System
UNDESA:	United Nations Department of Economics and Social Affairs
UNDP:	United Nation Development Program
UNEP	United Nations Environmental Protection
UTM:	Universal Transverse Mercator
WB :	World Bank
WB:	Waste Bin
WCV:	Waste Collection Vehicle
WG:	Waste Generate

Abstract

The unprecedented population growth, rising in community living standard (changing lifestyle) and urbanization have left most municipalities in developing Countries including Ethiopia grappling to find viable solutions to their waste management problems (health-pollution-degradation).The main objective of the study was to conduct locational analysis on solid waste bins by using GIS method in Adama Town. Data were collected both from primary & secondary sources and GIS based techniques were employed to analyze the data. Selection of locational analysis of the collection bins has been normally carried out by service area analysis using waste bins locations of existing and proposed at traveling distance of 200m, 300m, 400m and 500m, besides quantitative method for the time interval and frequency for the bins to replace. GPS used to take the co-ordinates of existing solid waste bins and digital camera used to take the image of the illegal waste dumped site. The result shows that insufficient solid waste management system due to insufficient number and uneven distribution of waste bins. The findings of the study revealed that scenarios at 500m trimming polygon location and 117 numbers of waste bins for the proposed waste bins are optimum for better collection services. The low time interval (2 days) and high frequency (15times) in a month for the existing solid waste bins. In contrast, the proposed ones have higher time interval (19 days) and lower frequency (2 times) in a month. In conclusion, the proposed solid waste collection systems have better economic and environmental advantage over the existing system. The implication of the study is that any policy directed towards the provision of effective solid waste management system in the Town should incorporate time interval to fill and frequency to replace waste bins at kebele level.

Keywords: *solid waste, waste bins, location of bins, time interval, frequency, Adama Town, Geographical Information System.*

CHAPTER 1: INTRODUCTION

1.1 Background of the Study

Rapid urban development facing developing countries including Ethiopia has come with serious environmental challenges concerning solid waste management. Solid waste arising from domestic, social and industrial activities is increasing in quantity and variety as a result of growing population, rising standards of living in most African countries and the development of technology (Eugene, 2013).

Solid waste management is a common term that encompasses a wide variety of activities and practices that describes unwanted residues of any given culture. All forms of human activity result in the generation of waste which can cause changes in the environment and harm to animals, plants and ecosystems. However, only a careful management will limit damage done to the environment and conserve scarce resources (Powell, 2001). SWM is an important facet of sustainable development for any country and global initiatives greatly support the prioritizing of SWM.

According to (UNDESA, 2005) of the Rio Declaration on Environment and Development affirms that environmental sound management of waste is one of the environmental issues of major concern in maintaining the quality of Earth's environment especially when it comes to sustainable development in all countries. The United Nations Millennium Development Goals (MDGs) by the September 2000 UN Millennium Submit reaffirmed sustainable SWM. In agenda 21, MDGs indirectly advocate sustainable SWM in the seventh goal which addresses environmental sustainability. This aims to foster the integration of the principles of sustainable development into country policies and programs (UNDP, 2007).

Waste generation dates back as far as man started roaming the earth. The abandonment of the nomadic life in later years led to the creation of permanent communities. Until recently, waste was given a low priority in most municipalities, conference rooms and government offices responsible for public health and safety (Pichtel, 2005). It was only way into the 19th century that the idea of collecting and disposing of garbage in a systematic fashion became part of the general drive to improve public health (Vlachos, 1993). In today's cities solid waste is removed and is either sent to disposal or is reprocessed for subsequent use.

The fundamental environmental issue in industrial and developing countries throughout the world is how to best collect MSW (Twardowska, 2004). As urbanization continues to take place, the management of solid waste poses major public health and environmental problems in urban areas of many developing countries. Thus development must be sustainable such that it is based on an integrated approach and interaction between social, economic and ecological. Sustainability therefore means reducing the ecological footprint while simultaneously improving the quality of life for ours and future generations within the capacity limits of the world (Lundström, 2007).

Solid waste has been an integral part of every human society and policies vary both within and between developing countries. The quantity of MSW arising from domestic, commercial, and industrial activities is not only the result of growing population, rising standards of living and technology development but also largely because of inadequate management system (Vhora, 2006). Environment is a sensitive issue, which is heading towards a potential risk due to unsustainable, waste collection and disposal system. The illegal waste disposals at open area, along road side and inside drainage lines causes environmental pollution and have become perennial problems for mankind (Ramasamy, 2002).

As one of the Towns of world, Adama Town is suffering from this perennial problem. Inadequate solid waste collection in the town has resulted in the accumulation of waste on open lands, at the edge of roads, in drains and in the residential areas, causing a nuisance and foul-smelling, environmental pollution, blockage of drains (Yonas, 2010). This situation is result in poor environmental conditions, which in turn present a formidable threat to health. Currently, the un-proportional number of waste bins with peoples (Lemma, 2007) one collection bins is used for more than 11,102 people which is five times greater than people to collection bins ratio (Yami, 1999), aggravates the illegal solid waste disposal.

Urbanization is bound to bring about concentration of population, which increases consumption and production activities in limited space. As a result, the generation of solid waste emanating from economic and social activities in urban areas is increasing at an alarming rate (Abera, 1997). Thus, the use of improved solid waste management technique that corresponds with the increasing generation of solid waste is crucial. However, the Adama Town waste management office have not been able to provide proper waste collection services due to manual method of collection systems, uneven distribution of collection bins, and insufficient number of bins (AMPRP, 2004).

The manual method for SWMS is lengthy and tedious work. Besides, there are possibilities of errors while merging the spatial and non-spatial data. However, there has been development of new technologies known as GIS for improving the waste collection systems by avoiding the above main problems. GIS have a lot of contribution to manage waste in the society with in a very less time and to handle various data streams and support-modeling analysis through various programs that acts interactively in GIS, as the work is carried in layers, there are least chances of confusion or error and the system is capable enough to coordinate between spatial and non-spatial data about the waste bins. GIS helps to manipulate data in the computer to simulate alternatives and to take the most effective decisions (Senkoro, 2003).

The methodology will be applied to the study area based on real field data like location of waste bins, waste generated, Population density, personal interview data, urban plan/parcel, road network and land use.

1.2 Statement of the Problem

Urban development in Africa in general and in Ethiopia in particular, while having brought significant benefits to the people such as employment and economic development has caused public healthy, aesthetic and environmental problems due to inadequate provision of basic services like water supply, sanitation facilities, transport infrastructure and waste collection (UNCHS, 2001). An improvement in the quality of life is accompanied by an increase in resource consumption and large amount of waste generated from various urban centers every day. Inadequate waste collection systems aggravates illegal disposal and burning of solid waste cause a profound strain on the environment; potential contamination of ground water resources, organic and inorganic pollution of nearby surface water.

In Adama Town, inadequate solid waste collection due to mismatch between waste generated and existing number of solid waste bins, uneven distribution irrespective of the density and optimum travel distance of the beneficiaries and poor spatial and non-spatial data linkage has resulted in illegal disposal of waste on streets, highways and drainage systems. According to the studies carried out by Lemma, (2007) the municipality is capable of collecting 43% of the waste generated in the town. However, the remaining 57% is indiscriminately disposed illegally in drainage lines, open spaces, street sides, and or is informally burned. Study by Yonas, (2010) indicated that out of the total solid waste generated in the town, about 40-50% properly collected and disposed but 50-60% remains uncollected.

The masses of solid wastes disposed illegally on open areas, along roadsides, stream courses and outside of the proposed containers etc. cause a breeding ground for flies, insects, bacteria, fungus and many such micro-organisms that could spread diseases and it would become worse during rainy season and the contamination might end up in some epidemic like cholera, malaria, typhoid pneumonia, bronchitis etc.

Figure 4.3: SW dumped illegally on open area (Photo by the researcher, 2014)

From the observations made in the existing system, the following conclusions were drawn which helps to frame the guidelines for proposing the new model for waste management in the case of study area. The existing locations of waste bins are not placed in convenient location and waste is not lifted at regular intervals. Many of the waste bins are overflow and spreading on the floors. In contrast some are filled half or few because the concerned body has no information about time interval and frequency and big disparity between waste bins and waste generating demand node of the town.

The above-mentioned problems are undisputable evidences of the poor waste collection system of the town. Therefore, this study opts to GIS based analysis of the location and number of solid waste collection bins in the service delivery of solid waste management in Adama Town aiming at proposing a means for the reduction of the quantity of solid waste disposed illegally outside of the container. Modeling using GIS is very essential and effective for locational analysis of solid waste in the study area.

1.3 Justification of the Study

The reasons why Adama Town was selected for this thesis is that the town is among the fast growing towns in the country that serve as the center of distribution of goods that are manufactured locally between economically important areas (Minjar, Arsi, Bale and Harar) where solid waste management problem is crucial, Adama has many resort and natural recreational sites such as Sodere hot water spring where most prefer to pass their weekend breaks there which creates additional waste burden to the town's waste management systems and to solve the lack of base line information about collection of SW as parts of SWM practice due to insufficient research conducted so far regarding locational analysis of waste bins and optimum number of waste bins.

GIS based approach was selected for this study to conduct locational analysis on solid waste collection bins for municipal solid waste management system in Adama Town because of its capability of avoiding possibilities of errors while merging the spatial and non-spatial data, identification of the accessible and inaccessible areas through pointing areas require attention, visual cross checking with statistical data, powerful tool throughout geodatabase building, managing large and spatial data analysis and provides a platform for presenting the analysis on map in a way that government officials can review their plan.

1.4. Objective

1.4.1 General objective

The overriding objective of this thesis was to conduct locational analysis on solid waste collection bins by using GIS method for Adama municipal solid waste management systems.

1.4.2 Specific objectives

More specifically, the study aspires to:

- analyze the functional status and geographical distribution of existing solid waste bins in Adama Town.
- determine the optimal number and location of solid waste bins for Adama Town.
- compute the time interval and replacement frequency of solid waste collection bins.
- compare different scenarios of existing and proposed solid waste bins in Adama Town.
- prepare solid waste collection bins replacement schedule of Adama Town.

1.5 Research Questions

In order to solve the previous thesis problems, the following research questions were designed.

1. What is the current status and spatial coverage of municipal solid waste management of the town?
2. What is the optimal number of solid waste collection bins of the town?
3. How can the optimal location of solid waste collection bins be identified?
   How the time interval to fill collection bins can be calculated to compute the frequency of its replacement?

1.6 Scope and Limitation of the Study

1.6.1 Scope of the Study

The study was confined to Adama Town, Ethiopia. MSW management systems comprises of all activities of waste management systems including waste generation rate, collection, storage, transfer, waste processing, transportation, and disposal. The scope of this study focuses only on the GIS based method for analysis of the location of waste bins and quantitative method for computing time interval to fill and its frequency to replace waste bins to generate base line information about collection of SW as parts and parcel of solid waste management practice of Adama Town. On the other hand, the problem that the researcher studied was restricted to current condition of MSW collection system (Number and capacity of collection bins, time interval to fill and frequency to replace collection bins for delivery of proper SWMS in Adama Town).

1.6.2 Limitation of the Study

The major limitations of the study are settlement and road network problems. The scattered type of settlement makes difficulty to cover demand node with the given distance range (facility number 06 and 01 only covers 159 and 162 demand nodes respectively which is below the standards of waste bins to people ratio) due to settlement problems and road network problems which is not fit with the screening criteria for network analysis and placement of solid waste collection bins around newly established area (*kebele* 03 and 14) and those accounts highest percentages from the problems make waste generating nodes out of the service domain.

The researcher does not consider the seasonal variation impacts on waste generation due to some factors like rainfall and special days like holly days for solid waste bins replacement schedule since it needs long time to analyze data at all season of the year and lack of map showing the location of the existing waste bins thus, the GPS data of the location of the collection bins with low accuracy level were used.

1.7 Significance and Beneficiaries of the Study

SWM is one of the major problems faced by town planners all over the world, especially in most large towns of developing countries like Adama Town the severity of the problem is manifested by increased urbanization, poor planning, and lack of adequate information to enhance the collection system of municipal solid waste management. This study play role in providing sustainable SWM services in the town by identifying the suitable location and proposing optimal number of waste bins and providing base line information for waste collection from computed time interval to fill and its frequency to replace waste bins at *kebele* level.

The beneficiaries of the research results will be researchers and academia, residents of the Town, governmental organizations and non-government organizations. The researchers and academians are the most beneficiaries from this finding because GIS based method of problem solving used in this thesis can help them as a base for further analysis to modify this finding or to study other related problems since there are many problems waiting solutions from researchers and academicians. Moreover, this study has numerous direct benefits to residents living in the Adama Towns in that; their surroundings will be free of odor, free of breeding ground for flies, insects, bacteria, fungus and micro-organisms which are risk to their health.

Governmental Organizations used this study to apply sustainable solid waste management in a friendly way with the environment. It will enable planners and policy makers in Adama Town to take appropriate actions that are helpful for improving efficiency in proper waste collection system because the scheduled collection based on computed time interval and frequency of solid waste collection bins provides base line information for planning and managing the SWM practices in an effective and efficient manner. Also non-government organizations use this thesis to implement different development strategy and sustainable programs in collaboration with SWM.

1.8 Outline of the Study

This thesis is organized into five chapters. Chapter One introduces the general introduction of solid waste management trends globally in general and in Ethiopia in particular. It includes background of the study, statement of the problem, justification of the study, objectives of the study, research questions, scope and limitations of the study, and significance of the study as well as outline of the study.

Chapter Two attempt to review the works of other academia and research institutions to posit the study within a large context of scholarly literature that relevant to the thesis topic, which contain information, ideas, concepts and evidence written from a particular standpoint to fulfill certain aims on the nature of the topic and how it is to be investigated and the effective evaluation of these documents in relation to the research being proposed. It also tries to provide broad theoretical concepts of GIS and SWMS, Empirical literature review, literature gaps, Conceptual frame work and lesson learnt.

Chapter Three tries to introduce the location, growth and development, physiology and drainage, population, climate and rainfall of Adama Town with the assumption that these have direct relations with the issues under investigation. It also gives detailed description of the way the data were collected and processed, the method employed to analyze the data, work flow of the study, materials and software used for the study. Chapter Four concentrates mainly on rigorous GIS based analysis and discussions related to accessible and inaccessible nodes, comparison of existing and proposed facility, proximity of SW bins, time interval and its frequency of replacement. Chapter Five deals with conclusions and result implications of the findings believed to be thought-provoking for stakeholders so as to solve the existing SW collection problem in Adama Town.

CHAPTER 2: REVIEW OF RELATED LITERATURE

2.1 Introduction

It is wise to have a brief overview of GIS before exploring its applications. Accordingly, many scholars considered the definitions, components and historical development of GIS. In 1950s GIS was developed to produce maps. Currently GIS technology has evolved and grown its objectives are expanding. As the result different definitions of GIS have been pop up. The major definition given to GIS is organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced data (ESRI, 2010). Generally GIS can be considered as an integrated system of computer hardware, software, and trained personnel linking topographic, demographic, socio-economic, utility, facility, image and other resource data that is geographically referenced.

GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps (Heywood *et al*, 1998). Therefore, GIS has become to symbolize a technology, an industry, a way of doing spatial work. It has come to promise a new world of disciplinary and professional integration. GIS allows mapping, modeling, and displaying large quantities of diverse data, all held together within a single database. Its power and appeal stem from its ability to integrate quantities of spatial information and non-spatial information about the environment and the wide repertoire of tools it provides to explore the diverse data (Chrisman, 1999).

Generally, GIS is all about the organized activity by which people measure aspects of geographic phenomena and processes; represent computer database to establish spatial themes, entities and relationships; operate upon feature representations to produce more measurements and to discover existing relationships by integrating different sources; and transform these representations to confirm other frameworks of entities and relationship. Therefore the components of GIS include software, hardware, technology, people and data (Heywood *et al*, 1998).

2.2 Contribution of GIS in Solid Waste Management

Geographic Information Systems (GIS) is one of the most sophisticated modern technologies to capture, store, manipulate, analyze and display spatial data (ESRI, 2010). These data are usually organized into thematic layers in the form of digital maps. The combined use of GIS with advanced related technologies like Global Positioning System (GPS) assists in the recording of spatial data and the direct use of these data for analysis and cartographic representation.

GIS have been successfully used in a wide variety of applications, such as urban utilities planning, transportation, natural resources protection and management, health sciences, forestry, geology, natural disasters prevention and relief, and various aspects of environmental modeling and engineering. Among these applications, the study of complex waste management systems, in particular siting waste management and disposal facilities and optimizing waste collection and transportation, have been a preferential field of GIS applications, from the early onset of the technology (Karadimas *et al*., 2007)

The selection of location of solid waste bins is a big question for local authorities because it represents a point of confluence of science, social science, and planning. Urban planners and city managers throughout the world are now confronting this issue within a much broader social development context. "Not in my backyard" may be the mantra facing decision makers as the volume of solid waste generated in rural and urban areas increases (UNEP, 1996).

GIS can be used as a decision support tool for planning waste management. Manual methods adopted for analysis of many factors would be a lengthy and tedious work. In addition, there are possibilities of errors while merging the spatial and non-spatial data. However, in GIS, as the work is carried in layers, there are least chances of confusion or error and the system is capable enough to coordinate between spatial and non-spatial data. The role of GIS in SWM is very large as many aspects of its planning and operations are highly dependent on spatial data. In general, GIS plays a key role in maintaining account data to facilitate collection operations; customer service; analyzing optimal locations for transfer stations (Ahmed, 2007).

2.3 Basic Concept of Municipal Solid Waste Management Systems

2.3.1 Definitions and sources of municipal solid waste

Solid waste can be thought as the items which are no more in use and are not expected to be used in future. In general, many authors and institutions define municipal solid waste as follows: Solid waste is the term used to describe non-liquid waste materials arising from domestic, trade, commercial, agricultural, industrial activities and from public services (Palnitkar. 2002). MSW is any material for which the primary generator or the users dispose of within the urban area. The MSW includes commercial and residential wastes generated in municipal or notified areas in either solid or semi-solid form excluding industrial hazardous (Ministry of Environment and Forest, 2004).

(ESI, 2004) also define municipal solid waste (MSW) as material, which is useless, or unwanted material discarded as a result of human or animal activity. Most commonly, it is solids, semisolids or liquids in containers thrown out of houses, commercial or industrial premises. According to Adama Town SWM department, SW is anything discarded as public sweepings, food remains, vegetable, ash, grass, metal, plastic, paper, dead animals and other materials that pose environmental and health risks.

The sources of SW are residential, commercial, institutional, construction and demolish municipal services, industrial, treatment plants sites, and agricultural wastes. According to the sources from which they emanate, solid wastes are usually classified as household, commercial, industrial, institutional, street sweepings and construction and demolition waste. However, sometimes scholars classify solid wastes in terms of their origin into three general classes: municipal waste (which includes domestic waste, street waste, commercial waste, market waste and hospital waste), industrial waste, and agricultural and animal wastes (Edelman, 1977). In Adama Town, the town Administration recognizes six major sources of solid waste components as households, street, commercial/ institutions, industries, hotels and hospitals (Lemma, 2007).

2.3.2 Physical Composition of RSW and factors influencing them

Waste composition is influenced by external factors, such as geographical location, the population's standard of living, energy source, rainfall, climate, habits of people what they eat and drink, the packaged material they purchase, etc. The composition of MSW stream is important for designing material recovery facilities and developing other waste minimization programs. Successful characterization depends on obtaining representative samples of the collected solid waste and making statistically precise and accurate estimates of component weights (Zingy. 2005).

As cities are becoming more urbanized, their waste composition is changing. The substantial increase in use of paper and paper packaging is probably the most obvious change. The other significant change is a much higher proportion of plastics and consumer products and more newspapers and magazines, more packaged foods and mass produced products are all the causes and bring with it more waste, of higher volume making waste more expensive to collect and a related rise in the amount of garbage. The percentage of RSW components vary with location, season, economic condition and many other factors (Holmes, 1981).

2.3.3 Generation Rate of Solid Waste

Generation of waste encompasses activities in which materials are identified as no longer being of values and either thrown away or gather for disposal. Uncontrolled or illegally dumped wastes are the obvious cause of the degradation of the environment and cause adverse effect for human health. Waste generation rates are affected by socioeconomic development, degree of industrialization, and climate. Generally, the greater the economic prosperity and the higher percentage of urban population, the greater the amount of solid waste produced.

The waste is generated in all areas but there is large variation in its type and quantity. The quantity and nature of the waste generated varies with the activities and with the level of technological development in a country. Large volume of waste is generated from households. For example, in Addis Ababa household waste constitutes 76% of total solid waste generated (Beyene, 1999). In Adama, similar to developing countries, the increase of solid waste generation is resulted from rapid urbanization and population growth. According to (Lemma,

2007) the amount of solid waste in Adama and other fast growing areas in the country has been increasing over time, largely attributed to rapid population growth rate.

2.3.4 On Site Handling of Solid Waste

On-site waste handling refers to the activities related to the handling of solid wastes until it was placed in the containers used for their storage before collection. Depending on the type of collection service, handling may be required to move the loaded containers to the collection point and to return the empty containers to the point where they are stored between collections. Factors that must be considered in on-site storage of solid wastes include: the type of container to be used, the container location, public health and aesthetics, and the collection method to be used (UNCHS, 2001). The Adama Town Sanitation and Greenery work process provides individual containers for few institutions, hotels, fabrics, offices, commercial establishments, garages, health centers.

2.3.5 Collection of Solid Waste

Collection is the functional element of solid waste management includes not only the gathering of solid wastes and recyclable materials, but also the transport of these materials to the location where the collection vehicle is emptied. This location may be a material processing facility, a transfer station, or a landfill disposal site. Collection of solid wastes in urban areas is difficult and complex because the generation of residential solid wastes is a mixed process that takes place in every home, every apartment streets, parks, and even in vacant areas of every community.

As the generation patterns become more mixed and the total quantity of wastes increases, the logistics problems associated with collection become more complex. The service of collection, transfer and disposals of solid-wastes in the urban areas of developing countries are either sparse or ineffective and the wastes are often improperly disposed of. About 30% to 50% of the solid waste produced in urban areas in the lower-income countries as well as poorest parts of middle-income countries is estimated to be left uncollected (Michael, 1999).

The collection system in many developing countries is done by using communal containers in which containers are placed at a place where the residents of the area are required to bring their refuse and dump-in. There are three basic types of collection equipment's: human powered, animal powered, and engine powered (John E., 1977). Solid waste collection system practiced in developing countries is carried out in four ways: communal collection, block collection, curbside collection and door-to-door collection (UNCHS, habitat, 2001).

Regarding solid waste collection, households have three options. The first option is that households take their solid wastes and dispose it in to a container nearest to their home. The second option is having contract agreement with micro and small enterprise associations (pre-collectors) to take their wastes to the container. The third option is that the municipality has assigned trucks and households can collect their wastes in to these trucks. All the three options are available at centers and main roads; the peripheries dispose their wastes at ditches, roadsides, riverbanks etc.

2.3.6 Effects and Impacts of Solid Wastes

If solid wastes are not managed properly there are many negative impacts that may result. In order to give more emphasis for the management work, one must have a good understanding about the effects and risks that may arise from improperly managed solid wastes. As described by (Tchobanoglous *et al,* 1977), the public health, aesthetic and ecology are found to be the most important effects associated with uncontrolled solid wastes.

The concerns of public health are related primarily to the infestation of areas used for the storage of solid wastes with vermin and insects that often serve as potential reservoirs of disease. The practice of throwing wastes into unpaved streets, road ways and vacant land led to the breeding of rats, with their attendant fleas carrying the germs of disease that result in disease outbreak. The lack of any plan for the management of solid wastes led to the epidemic of various diseases. The most effective control measure for both fleas and rats is proper collection of SW.

Aesthetic considerations are related to the production of odors and the unsightly conditions that can develop when adequate attention is not given to the collection of SW in effective way. aesthetic can be maintain by providing the optimum number of containers for SW collection that minimizes the probability of illegally disposing waste on open area, along road side and in side drainage channels and with the keep of a reasonable collection frequency. Ecological impacts, such as water and air pollutions, also have been attributed to improper management of solid wastes.

2.4 Empirical Related Literature Review

A study conducted by (Mujibor Rahman *et. al*. 2008) in Khulna City, Bangladesh on GIS Application for suitable location of waste bin for SWM in Khulna University of Engineering and Technology from Department of Civil Engineering to reduce illegal dumping of waste by using application of GIS. Then from the GIS planning opportunity of waste bin location selecting in some part of Khulna city the researchers obtained the following results. 66.57% of waste collected by Khulna City Corporation with the existing bin and haul container. So problem arises when 33.41% waste are illegally dumping can causes various environmental problem and diseases. To improve this SWMS new waste bin in 200m optimizing distance is provided essential to collect 92% waste in the study area. Waste bin location and Service area of a bin can be calculated accurately using Network Analysis function in GIS software.

A study was made by (R.Nithya *et al*, 2012) to analyze optimal location and proximity distance of municipal solid waste collection bin using GIS in Coimbatore city. The researcher examined the environmental and cost effectiveness of using GIS in municipal solid waste management system by determining optimal location and optimal number of SW collection bins. Further to facilitate MSW management, the enhanced options are to be provided for initial functions of MSW such as collection and transportation. The environmental and cost effectiveness of the functions would be achieved and analyzed with adopting scientific technology like GIS.

The proposed numbers of collection bins were assessed according to MSW generation. Then the optimal positions were found with reference to existing bin locations, road network and population density. Moreover, based on the public preferable walking distance to drop the MSW to the collection bin, a model was developed with three different proximity distances of 50m, 75m and 100m around existing and proposed bins and found the optimal distance. As a result, the entire area was covered by 75m distance around the collection bin with 99%. Thus, the proposed model suggested better modifications in existing system and which would recommend best possible collection services.

(Tesfaye, 2011) conducted a study on GIS based analysis of the location of collection bins for municipal solid waste management system in Arada Sub City, Addis Ababa with the main objective to analyze the location and number of solid waste collection bins in the service delivery of solid waste management of Arada sub-city using GIS technique at traveling distance or trim polygon of 100m, 200m, 300m, and 410m) and the accessibility is greater than 97% for the proposed SW bin. This implies that the proposed solid waste bins location is at a proportional location.

In Adama Town (Lemma, 2007) conducted a study on Household Solid Waste Generation Rate and Composition Analysis in two Selected *Kebeles* by using questionnaire survey of 162 households regarding distances that a container apart from their houses and the results implied that most of the households are far away from the containers. Only 21.6 % are within the radius of 100 meters, 26.5% are found in between 100-200 meters. The rest 32.7% of the households have to move more than 500 meters to reach the container. Even there are families (6.8%) who do not know where the container is located.

2.5 Related Literature Gaps

After reviewing the related literatures the researcher identify the following gaps. A study on Analysis of households' preferences for improved SWM in Adama Town using Application of choice modeling and household solid waste generation rate and Composition analysis in two selected *kebeles* have gaps in the approach because the objectives of the two studies more focused on non-spatial data rather than spatial data even though SWMS more depends on geographical data and poor linkage (possibility of errors while merging spatial and non-spatial data). Moreover, the ways of comparison analysis of existing and proposed systems have limitation to more visualize the existing SW situation with the proposed approach.

2.6 Conceptual frame work and Lesson learnt

The Conceptual frame work designed by different researchers from related literature review that provides the basis for the proposed study were: Collection of data about the existing waste management situation in the study area from different sources with the ways it brought together in one plat form to be linked together and correlated, Preparing a database, Analysis of present situation to recognize problems as well as limitations in study area waste management, Discussion and critical analysis of SWM models presented in literature studies, Design and implementation of GIS model, and problem analysis using GIS.

Also, the researcher learnt from the literature review that in developing countries the main cause for almost all problems in SWM is the poor spatial and non-spatial data linkage. The issues like high waste piles on streets, inadequate waste collection, high operational costs, long routes and scattered location of collection bins are pronounced to be applicable under poor linkage of spatial and non-spatial data in SWM. The researcher also learnt from the literature reviews that GIS based approach was the best solution for the above mentioned problems as it has a great facility for geographic features and their attributes in a computer database and no possibility of errors while merging spatial and non-spatial data since.

GIS could help in dealing with several factors simultaneously that needs to be considered while planning waste management. The WM issues are considered to solve some of the present situation problems like proper allocation and relocation of waste bins, check for unsuitability and proximity convenience due to waste bin to the users, proposal of waste bins for the required areas. GIS provide large economic and environmental savings through the reduction of solid waste emptying frequency and proximity distance between demand node and SW facility. Generally, the researcher concluded from review of related literature the GIS spatial techniques is a good decision to analyze location and number collection bins for effective SWMS.

CHAPTER 3: DESCRIBTION OF STUDY AREA AND RESEARCH METHOD

3.1 Description of the Study Area

3.1.1 Location

Adama Town is located about 99 km along old road and 75 km along new road east of Addis Ababa enclosing between 8^{o}33`35``N to $8^{o}$36`46``N latitude and 39^{o}11`57``E to $39^{o}$ 21`15``E longitude covering an area extent of about 133.6 km^{2} with an average altitude of 1620m above mean sea level. It is found on a nodal location along main national and regional transport lines from the capital Addis Ababa to other important towns. It is also situated close to natural recreational sites such as Sodere, Boku etc. The administration of the town is subdivided into 14 urban *kebele* administrations Messay (2010)

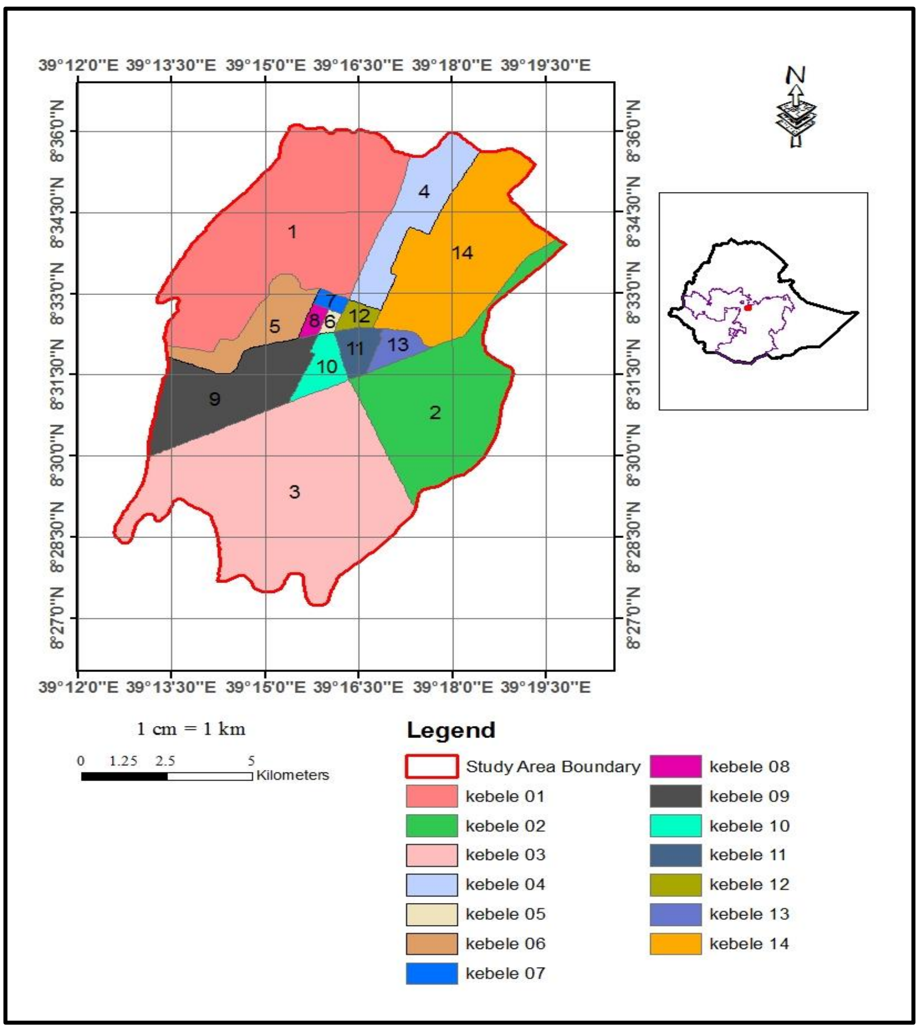

Figure: 3.1 location map of study area (source of base data: Adama municipality)

3.1.2 Historical back ground of Adama Town

Adama is one of the towns in Ethiopia which started as a small railway station along Ethio Djibouti railway line. In the existing regional road network of the country, Adama is located at the point of intersection of the Addis Ababa Harar route and the fertile regions of Arsi and Bale. The original location of Adama was the plateau to the west of the existing town, the place on which the new Administrative center is being built now. It is said to be established in the early 1920s.

Like the traditional classic cities the town can be seen in its entirety due to its relation to the topography. But, this location was not a result of any planning. The first settlers of Adama were employees of the railway station. The first structures were the railway station and a handful of houses constructed by the railway company. Later on, farmers from the surrounding region started to settle near the station in search of the station's water supply and other facilities. The first major transformation of Adama took place during the Italian occupation (1936-41).

The Italians had contributed greatly to the town's development and growth. They built the town with a new plan connecting it with many of their provincial centers by telephone, telegraph and radio networks. Newly developed roads also connected it with Addis Ababa and other regional states. Even after their withdrawal the Italians have continued to contribute to the growth and stability of Adama. Thus, as a compensation for their atrocities during their occupation, they built the Awash Hydroelectric power plant which provided electricity to Adama as well as other parts of the region. There was no piped water supply at the time. People used to fetch water from Awash River which is about17 km to the south traveling on foot.

After the Italian period of 1936-41 Adama continued to play an important role in the administrative and economic life of the country. It became the administrative center for Yererna Kereyu Awraja. The town became a hub of a number of courts, public offices as well as security and armed forces. Adama, which was the original name of the town, was changed, in 1944/45, to Nazareth by Emperor Haile Selassie I marking an increasing attention it started to get from the rulers of the time. However, it got its original name back after the 1991 change in government (Addis Mebratu, 2006).

3.1.3 Population and Socio-economic characteristics of Adama Town

Important activities of a given society are governed by socio-economic and demographic characteristics. Hence, having good insight about socio-economic and demographic character is highly relevant for the study. It is useful for formulating various development plans and evaluating purpose. Adama is a town of migrants, who came following the trade route in search of jobs and livelihood. Thus, it is composed of people of different ethnic origin.

Economically, Adama has been serving as a major focal point for trade and small scale industries. The town is an important center of distribution of goods that are manufactured locally by the various industries in the town and its residential area bordering the town. It still is a relay point for goods produced and manufactured in the country and imported from abroad to the small towns and rural areas in the region. As a result, it seems the two primary market places Gimb and Arada are characterized by wholesale trade side by side the retail for the town dwellers.

Adama also serves as the loading center for some Ethiopian export goods particularly cereals. As a result it is characterized by lots of warehouses. Even before the 1960s there were 40 to 50 warehouses. This number has been growing ever since. Due to its location on route to the Sodere hot water spring resort, and its strategic importance as an intersection point between economically important regions Adama has always been full of travelers. Recently, Adama has also become famous for its meat trade which attracts visitors from Addis which flock in every weekend. Thus there are a lot of hotels big and small, restaurants, bars and cafes and the majority of the population gets its livelihood from various commercial activities and services.

The 1961, 1967 and 1978 population sample survey for Adama Town revealed that the population of the town was 123,934, 171,351 and 172,382 respectively. The 1984 census put the population of Adama Town at 173,420; the 1994 census recorded 198,213 people while the 2007 census come up with the population size of 222,035. There is an increase of 98,101 or 79% increase over the year 1961-2007 with the annual increment of 1.72 % (CSA, 2007). 2015 projection census come up with the population of 306,831 and there is an increase of 84,796 over the year 2007-2015 (CSA, 2015)

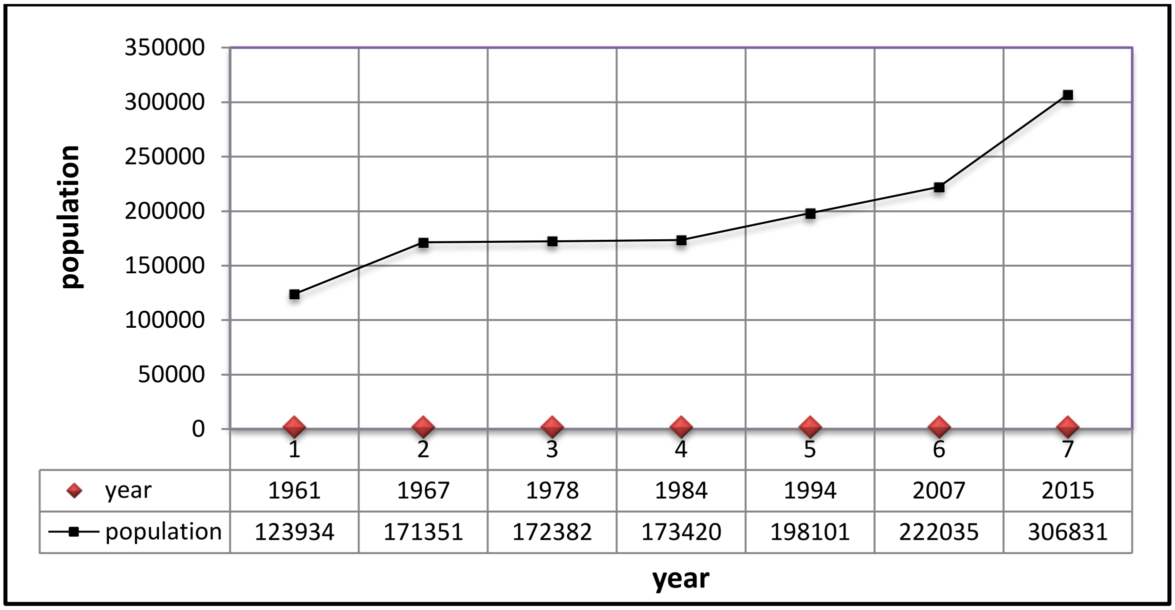

Figure 3.2: Population of Adama Town from 1984 to 2015 (CSA, 2015 projection)

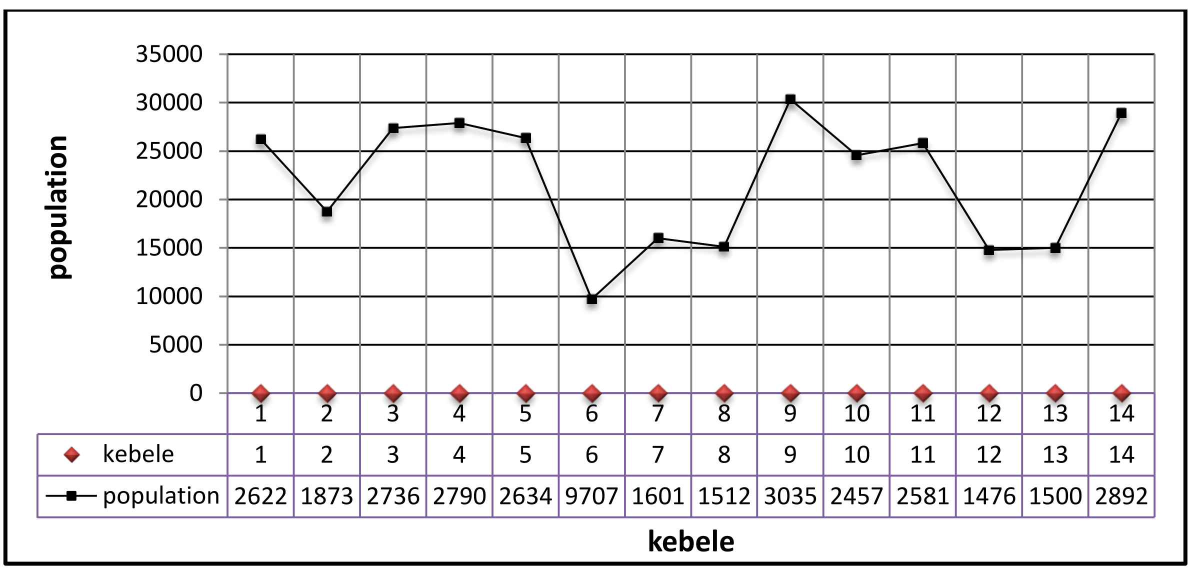

Figure 3.3: Population of Adama Towns at *kebele* level (CSA, 2015 projection).

3.1.4 Physiology and drainage

Adama is found within the wonji fault belt, which is one of the main structural systems in the Ethiopian Rift Valley. Its physiographic condition is therefore, mainly the result of volcano-tectonic activities that occurred in the past and also partly the result of the deposition of sediments which are considered largely of fluvial and lacustrine origin. Adama is regarded as seismically active area concerning earthquake hazards with the probability occurrence of 0.99 in every 100 years (NUPI, 1995). The altitude of Adama varies from about 1600m to 1970m above mean sea level. The only perennial river in the vicinity of Adama is Awash into which all the streams in the town join (NUPI, 2005).

3.1.5 Temperature

The mean annual temperature is 21.6^{o}c. It can be classified as semi-humid to semi-arid climate, which characterizes the altitude range 1300 to 1800 above sea level. In Adama the hottest month with maximum mean temperature of 30.6^{o}c is May. The monthly minimum mean temperature is November and December with the temperature of 13.0^{o}c. The monthly maximum temperature varies between 25.8^{o}c and 30.6^{o}c while the minimum monthly values vary between 13.0^{o}c and 18.3^{o}c. At Adama, the heavy truck movements could contribute to the increment of temperature due co_2 input into the air (NMA, 2015)

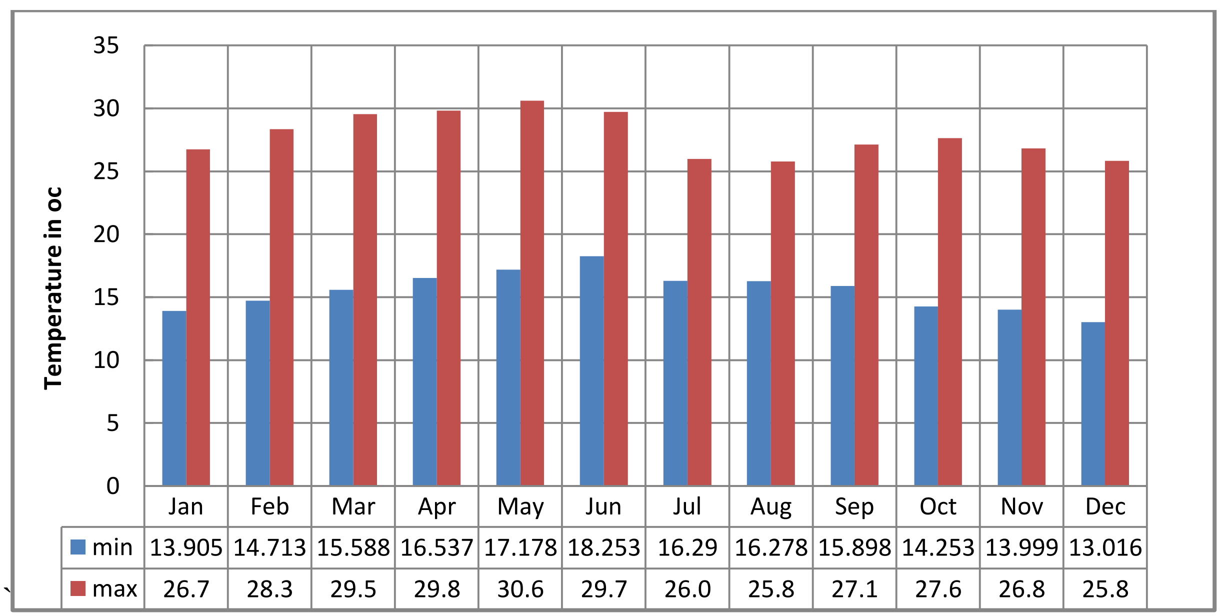

Figure 3.4: Minimum and Maximum Monthly Temperature at Adama Town

3.1.6 Rain fall

Rain fall recorded at Adama meteorological station for the past 10 years (2004-2013) indicated that the average annual rainfall is about 885.91mm. The maximum monthly average rainfall is about 224.733mm in July. Most of the rain occurs in summary season (June to September).

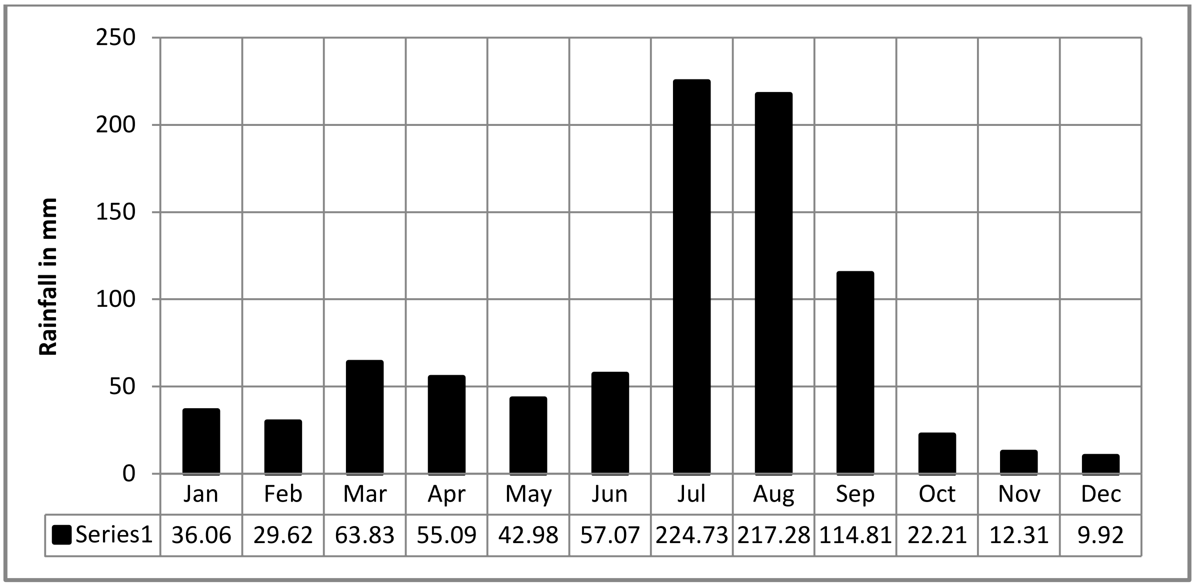

Figure 3.5: Mean Monthly Rainfall of Adama Town

3.1.7 Nature of the Soil

The characteristic of soil is a result of topography, climate and type of parent material, age and environment. The soil development in the Adama catchment is mostly due to the physical disintegration and decomposition of volcanic rocks, deposition of alluvial and ashes. The weathering products are either remain in places and form residual soils and deposited in the low land centeral and southern parts driven by over land flow (Dagnachew, 2011).

Although there is significant difference in the degree of weathering on the slopes of ridges, the soils formed there will be rapidly eroded and result in thin soil cover. In the localities where the topography is plain to gentle, the soil has thick profile. The type of parent material and the length of time to which the parent material is subjected to weathering, control the variation in the thickness of soil. Generally, the soil deposited on the plainly land of Adama is reworked alluvial sediment and has longer deposition time. As can be conducted from the well log data of bore holes drilled in the town, the depth of the soil reaches up to 20m around melka Hida (Dagnachew, 2011).

3.2 Research Methods and Materials

3.2.1 Reconnaissance survey

Before actual field data collection, reconnaissance survey and discussion with the Adama Town sanitation and greenery work process office staffs and then solid waste management micro and small enterprise coordinator was made from February16/02-26/02/2014 in order to obtain information about the distribution and location of solid waste bins in the study area, number of waste bins, capacity of waste bins, solid waste bins emptying frequency, etc. for the aim of getting some mental picture about study area SWM practices for further analysis.

3.2.2 Method of data collection

Both primary and secondary data used in this thesis. For gathering primary data researcher employed Key Informant interviews, GPS survey and field observations methods. Primary data about the SW of the study area were collected by using Key Informant interviews with Sanitation and greenery work process head and MSE service providers about the overall SWMS of study area and GPS survey was used for collection of data about spatial distribution of SW bins, location of the solid waste bins, and illegal waste disposal sites.

Apart from these, the researcher used field observation method for this study. Field observation was employed for assessing spatial distribution of MSW bins, household’s SW handling practices and illegal dumping. Photographs were taken during field observation for partial exposure of transfer stations, illegal dumping of residents. On the other hand, secondary data were extracted from different sources including published and unpublished materials.

Table 3.1: Data Source, purpose and description

Data	Source	Its purpose	Time
Study area boundary	Adama municipality	For defining study area boundary	
Population density	CSA of Adama	To estimate the waste generation rate	2007 and 2015 projection
LU	Adama municipality	To identify waste generating areas	
Road network	Adama transport office	To place the proposed solid waste bin	2014
Existing location of the SW bins	Adama municipality	To evaluate functional status of bins	2014
SW density, SWG, bins capacity	Adama municipality	To compute time interval and frequency	2014
Building parcels	Adama municipality	To generate the demand centroid	2014
Adama Town Aerial photo photographs (0.15*0.15m resolution)	EMA	To generate parcel node, Road network and steam buffer	2014
LULC map	Adama municipality	To determine waste generating nodes	2013

3.2.3 GIS Based Service Area Evaluation Method

A network service area is a region that encompasses all accessible roads (roads that are within specified impedance). A service area created by network analyst also helps to evaluate the accessibility. Concentric service areas show how accessibility varies with impedance and is possible to use service areas to identify how many people, how much land, or anything else is within the neighborhood. The service area analysis layer stores all the inputs, parameters, and results of service area analysis. When the service area analysis layer was created, it shows up on the network analyst window along with three categories: Facilities, Lines, and Polygons. Furthermore, the service area analysis layer shows up in the table of contents as a composite layer Service Area Analysis Scenario one, Service Area Analysis Scenario two and so on composed of three feature layers: Facilities, Lines and Polygons.

Accordingly, the required data for the analysis were road network, land use, parcel centroid that represents demand nodes, stream buffer, existing and proposed waste bin location feature classes were used in network analyst toolbox. It is known that similar spatial reference and other geographic parameters are of high importance to do a successful spatial analysis. Therefore, in this case, the datum and spatial reference system for the used datasets are Adindan and UTM_Zone_37 North respectively.

Location of the proposed bins is determined based on travel distance from each demand node to the nearest bin by trail-and-error technique taking heed of different distance ranges from 200, 300, 400 and 500 meter were taken into consideration and the optimum number of waste bins was based on the waste generated from each demand node on monthly basis. Thus, 100 waste bin new locations were selected in the town in addition to the existing 17 meets the criteria for placement of solid waste management from a total of 20 functional solid waste bin locations that were collected by GPS survey and 3 of the functional status SW bins void from analysis for the reason that their placement not meets the criteria for placements of solid waste bins with the total of 117 solid waste bins.

In order to locate the proposed solid waste bins the followings were used: existing waste bin locations, demand nodes, road network, steam buffer and land use. The locational data of each type of facilities was used for generating the service area polygon with a specified trim polygon distance which is useful in defining the accessible demand nodes from the point location of facilities in question. The demand nodes were used to determine the amount of waste generation from point location on monthly basis by considering the total number of households. The road network was used to select the possible location of the waste bins and the land use was used to categorize the waste generating and non-waste generating nodes from the extracted demand nodes and 15m buffer distance from stream or flood plain. Consequently, the shape file based network dataset was built using the selected existing road network, demand and supply nodes using network analyst extension in ArcGIS environment. The general methodology used for the thesis is shown in Figure 3.6

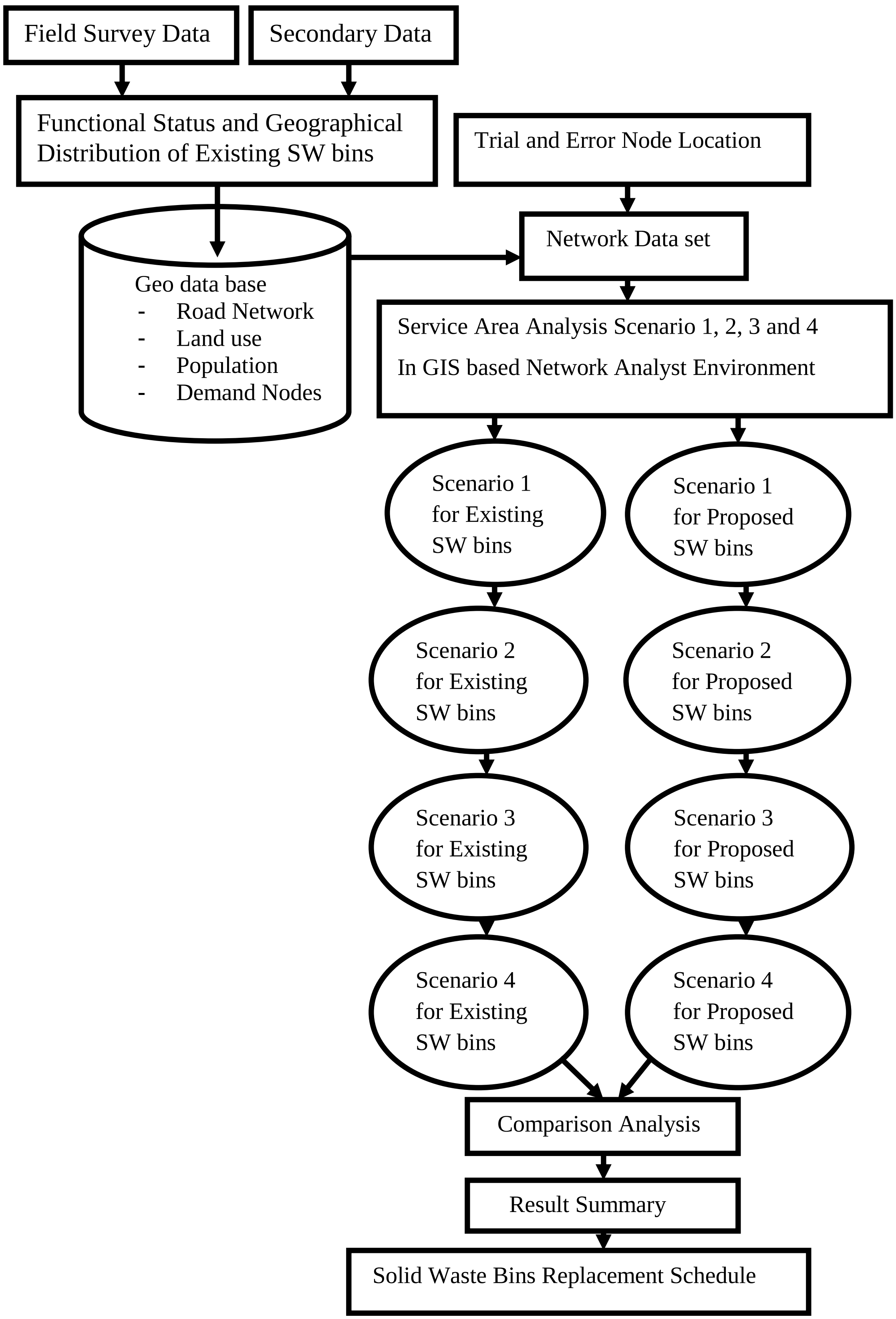

Figure 3.6: work flow of study area

3.2.4 Methods of data analysis

Service Area Evaluation and Quantitative methods were used for the analysis of data obtained from field survey and interview. GIS technique known as service area analysis used to find optimal location of bins based on demand node, road network and land use and optimal number of collection bins based on waste generated from each demand node. Quantitative technique used to calculate time interval and frequency based on demand node, solid waste density, solid waste bin capacity and waste generation rate per day to determine solid waste bins replacement schedule of the town.

3.2.5 Materials used

GPS and digital camera were used to take the co-ordinates of existing SW bins and to take the image of the illegal dumped waste respectively. ArcGIS Network Analyst in ArcGIS 10.1 was used to find the service areas around the location of the SW collection bins on a network. To carry out the analysis materials like GPS, Digital camera and software like ArcGIS, Erdas Imagine software etc. were used (See Table 3.2).

Table 3.2: summary of materials and software used to execute the study

Nº	Item(materials)	Purpose
1	GPS (Garmin etrex10)	for collecting coordinate of existing collection bins
2	Digital camera	for taking image of illegal dumping site
3	GIS software version 10.1	for service area analysis, producing maps and graphics, data extraction and statistical manipulation and report generation
4	Erdas Imagine software Version 9.2	for data pre-processing(georeference, radiometric correction, mosaicking and masking or clipping air photo of study area
5	Microsoft excel software 2010	for statistical analysis of distribution of existing collection bins at kebele level, population, rainfall and temperature
6	Microsoft word software 2010	for writing purpose
7	Topo map Sheets of 1:50,000	For georeferencing study area aerial photographs

CHAPTER 4: ANALYSIS, RESULTS AND DISCUSSIONS

4.1 Solid Waste Collection Operation in Adama Town

This chapter tries to analyze the main findings of the field survey and the major factors determining the performance of solid waste collection in Adama Town. To this end, findings from field reconnaissance, field survey and key informat interviews held with micro and small enterprise were included. The mismatch between demand node and number of existing collection bins, uneven distribution and unscientific method followed to allocate the bins leads to more dumping of MSW in the drainage, on open area and along road side (figure: 4.1, Figure: 4.2 and Figure: 4.3).

Figure 4.1: SW dumped illegally in side drainage lines (Photo by the researcher, 2014)

Figure 4.2: SW dumped illegally along roadside (Photo by the researcher, 2014)

4.1.1 Solid Waste Collection

The data from the SWM office of the Adama Town reveals the rate of municipal solid waste generation for the town was estimated to be about 0.35k.g per capita per day in 2014. During this time the population of the town was approximately 306,831(CSA, projection of 2015) this means that the amount of solid waste that was generated during the given year was on the average about 107,390 kg by weight or 290.24 m^3 by volume. However, the SWM department of the town collecting and disposing only 130.6 m^3 of solid waste per day. Waste collection by MSEs in the town is done through door to- door service. Prior to MSEs Service, since municipality trucks cannot reach all the areas, households living around roadsides were the only beneficiaries from the service. This role of MSEs further improves the frequency of trips that the town can make than before the MSEs were likely to intervene in this kind of service.

Figure 4.4: MSEs transporting SW to municipal SW bins (Photo by researcher, 2014)

Other than the two waste collecting systems, in the town SW is also collected with the help of litter waste bins. There are 178 waste bins installed along main roads in Adama Town. These litter waste bins are essentially designed to collect pedestrians' very light and little volume of pieces of solid wastes like napkins, residue of vegetables, pieces of paper etc.

Figure 4.5: Litter WB Installed along main roads of Adama Town (Photo by researcher, 2014).

Solid waste collection is performed in two ways: residential waste is collected by MSEs, whereas street clearing service is delivered by the permanent workers. According to the Head of Sanitation and Greenery work process of the town, these permanent workers clean regularly only the main roads rather than the arterial and sub-arterial roads because their number cannot cover the existing wide range of activities.

4.1.2 On Site Storage Solid Waste Collection bins

In Adama Town there are 20 standardized containers. The optimum holding capacity of each container is $8m^3$ and the containers are open top. $1m^3$ solid waste equals to 370 kg by weight (Solomon, 2011). So, it is believed that these 20 containers can hold $160m^3$ (59,200kg) of solid waste at a time. The distribution of SW bins is an important issue that needs a serious attention. Waste bins have to be distributed in a way that it considers the distribution of the population and the rate of solid waste generation on one hand, and the optimum distance that beneficiaries travel, on the other.

Adama Town has fourteen *kebeles* and out of these *kebeles, kebele* 02, 03, 06, 08, 10, 12 and 13 do not have waste bins. These seven *kebeles* that have no waste bins are being served by the door-to-door collecting MSEs. The distribution of containers among the *kebeles* is not uniform. It is because of this that some kebeles have more facilities than others. For example, kebeles 01, 04, 05, 07, 09, 11 and 14 have 1, 5, 3, 1, 4, 2 and 4 waste bins respectively. Besides, some of the residents that live in remote areas do not benefit from the container service.

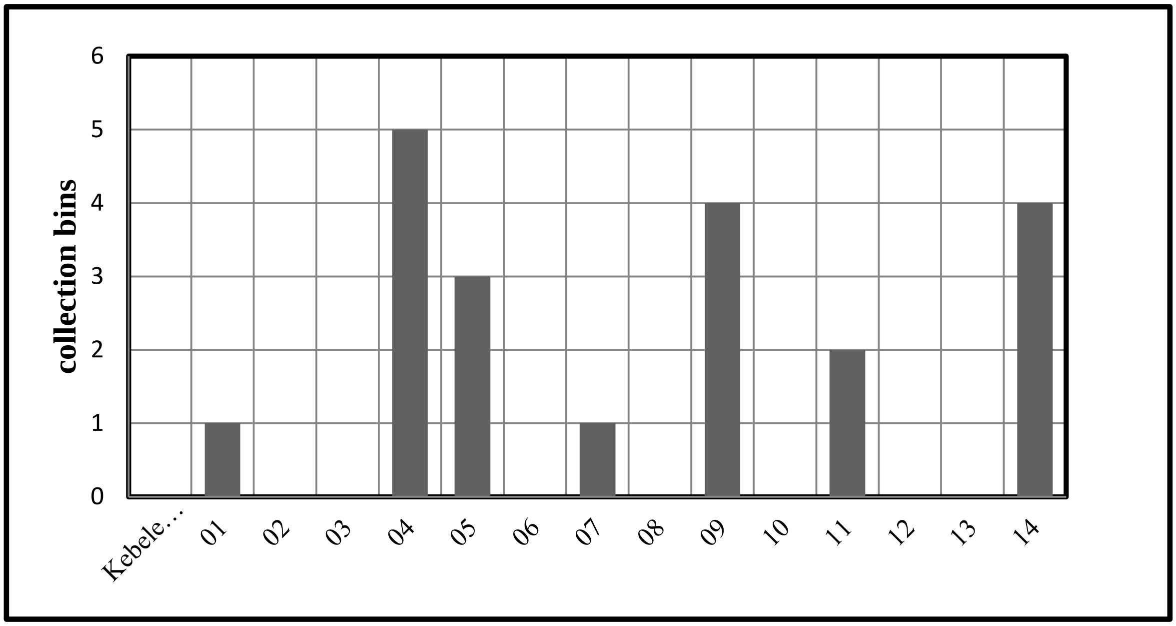

Figure 4.6: Distribution of $8m^3$ solid waste collection bins in Adama Town

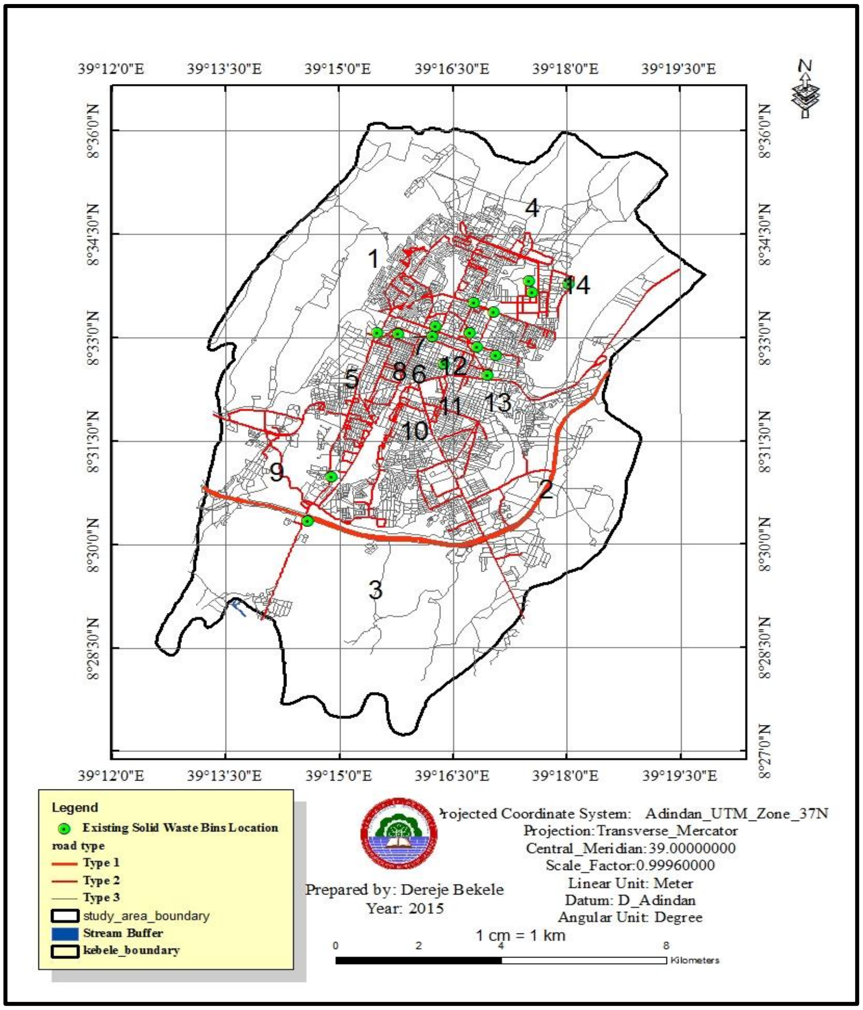

Figure 4.7: Functional and Appropriately Placed SW bins Location map

4.1.3 Solid Waste Collection Bins Allocation Criteria

According to the Head of the SWM office, the criteria used by the solid waste department of the Adama Town to allocate waste bins in selected places are: The place where SW collection bins should be located has to be suitable for vehicles to come and pick up the SW; Make sure that the location of these solid waste collection bins can best render the service to the households and Having an approval first as to whether the kebele is willing to give a specific place for placing solid waste collection bins, etc.

Based on the above pre-conditions used as criteria, the 20 containers were distributed to seven *kebeles*. In the field survey, it was also observed that wastes that were generated in different institutions were collected in $1.1m^3$ small size containers. These small size containers were placed in the compounds of different institutions. In any case, the discussions held with concerned residents in the town and the interview held with members of the MSEs indicated that the existing solid waste collection bins in the town do not agree with the total population and the rate of generation of solid waste.

Even though individuals perceive solid waste management differently, what is true is that waste collecting containers, are inadequate in the town. Furthermore, these inadequate waste bins are not meant only to collect household wastes but are also required to collect waste from street cleaning. An observation made on the use of the waste bins found around Gimbi Market showed that these containers could not accommodate the solid waste that would be collected always on market days. The reason for this is that, since there is a large market left over from the sale of commodities like plastics, cardboard, residue of 'Chat' etc. would be a challenging heap of rubbish.

4.1.4 Solid waste bins emptying frequency in Adama Town

Waste that is produced per day and number of existing bins has an impact on the emptying frequency of vehicles. Areas that have high volume of waste with limited waste bins should get priority in emptying frequency. If this is not the case, the high volume of waste that is not collected timely will not be manageable because its environmental cost will be high. But as stated earlier, the existing vehicles cannot transport those containers that are full to the maximum. Despite all this information, waste bins were full of heap of rubbish and waste up on the ground because most of the vehicles are not operational. The following table shows the emptying frequency of containers in Adama Town.

Table 4.1: solid waste bins emptying frequency in Adama Town

Kebele	Emptying intervals in days					
	Daily	**Once in two days**	**Once in 3-5 days**	**Once in 5-7 days**	**Once in month**	**WB not available**
01		✓				
02						Nil
03						Nil
04			✓			
05		✓				
06						Nil
07			✓			
08						Nil
09			✓			
10						Nil
11		✓				
12						Nil
13						Nil
14		✓				

Source: Sanitation and Greenery Work Process Office

It is observable from (Table 4.1) that *kebeles* 02, 03.06,07,08, 10, 12 and 13 do not have SW collection bins. The reason for this is that in adequate number of SW collection bins facility and no scientific procedure followed for their placement. Therefore, those residents who do not use the service of MSEs and forced either to travel a long distance and dispose of their wastes in the municipality collection bins or they use different mechanisms like burning in the compound illegally disposing of wastes in different places like along main roads or in open drainage channels etc. Emptying of collection bins in the town is randomly done (have no regular schedule for collection bins replacement).

4.1.5 Establishment of MSE's on solid waste management in Adama Town

In the literature, some scholars argue that urban service delivery should not be only the task of local governments. For efficient and proper service delivery, the role that private institutions play is very important. Currently there are four types of MSEs: Street cleaning (25 associations with 455 members), flood drain cleaning (11 associations with 127 members), primary collectors (40 association with 480 members) and 3 secondary collectors in Adama Town. An interview made with some of the members of the MSEs revealed that even though solid waste collection is a very tiring task, being a member of the MSEs has created job opportunities for them and this has initiated other jobless people to join them (Annex 4).

4.2. Data Analysis and Results

4.2.1 Data preparation

After collecting all the necessary data the next step was tracked to preparation of the data for analysis. This required changing of data formats, georeferencing, digitizing and building the road network database, digitizing parcel nodes, digitizing streams, connecting demographic and social economic data to each administrative unit to manipulate statistics, editing and joining attribute data and adding missing attributes. The general steps followed from data pre-process to data analyses are: Data pre-processing (Georeference, radiometric correction, mosaicking and clipping Adama Town aerial photo), Data extraction (digitizing road network, demand node or parcel node and streams from clipped aerial photographs of study area) and Data Analysis (Annex 5).

After preparation of the data, for the improved SW collection process, spatial geo-database was designed and implemented, using a standard commercial GIS environment (ESRI, ArcGIS). Road network, demand node, steam buffer, existing solid waste bins, proposed SW bins and study area boundary were extracted and exported to shape file and stored geodatabase to sustain for future use enable to assess their accessibility and to create network and service area analysis.

4.2.2 Layer development for service area analysis

While determining service area polygons of the bins, service area analysis segment was developed from lines (road network), facilities such as existing and proposed waste bin location. Consequently, road network analysis layer were extracted by attribute sub setting technique by considering the road width field in the attribute table of the feature class for selecting optimum road width for placing the SW collection bin. Therefore, in this case those road links that are greater or equal to 15 meters were selected and extracted (Figure 4.7).

Waste bin locations were generated in two ways. First, the existing waste bin location coordinates were exported to ArcGIS environment as database file format for creating point event layer. This point event layer was exported to shape file format to make it permanent existing facility analysis layer (Annex 2). Secondly, digitization in point mode was used to locate proposed bin location considering the road intersections and the extent of the service area polygon generated from demand nodes' location point of view. To sum up, the shape file-based network dataset was built from road layer and, facilities analysis layer (Figure 4.8).

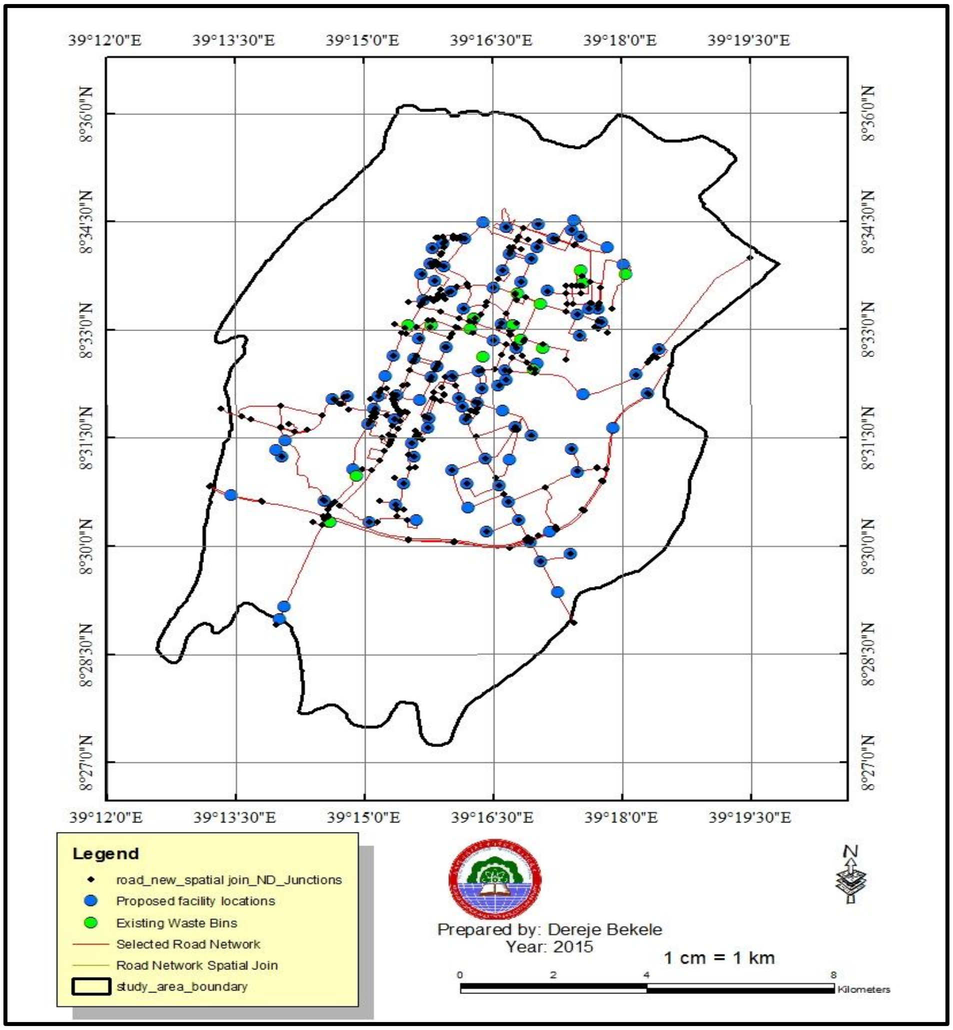

Figure 4.8: Network data-set development from existing and proposed facilities

4.2.3 Service Area Analyses

The service area solver generates polygons or lines that cover all edges within a given distance, travel time or other impedance unit from the predefined facility/facilities. A network service area is a region that encompasses all accessible streets (i.e. streets which are found within specified impedance).In order to cover the services for the demand nodes or parcel nodes in the town different service area analysis polygons were generated using the trial and error method. As it is mentioned above, the four distance values (200, 300, 400, and 500 meters) were considered as polygon trimming distance for the final service area polygon generation for both types of facilities such existing and proposed ones. This circumstance creates eight analyses. These scenarios are classified in to two based on the types of waste bins used namely: four distance values against existing waste bins and four distance values against proposed waste bins. Thus, the results of the service area analysis for the existing as well as for the proposed facilities are shown in the following figures and tables.

Scenario one: 200m trimming distance for existing waste bins

This scenario illustrates that more than 8,930 or 13.24% of the waste generating nodes are served and due to the mismatch between waste generating nodes and number of existing waste bins, unequal distribution of the existing waste bin locations and the shorter trimming distance causes for about 58,525or 86.76% of waste generating nodes to be out of the service domain in the town. This implies that the northwest, southeast and most parts of southwestern of the town are not served at all from the existing waste bins. Consequently, due to the absence of nearby waste bins the un-served demand nodes dispose their waste illegally on the roadsides, on open area, in drainage channel etc. and create environmental pollution as well reduce the beauty of the town at large (Figure 4.9).

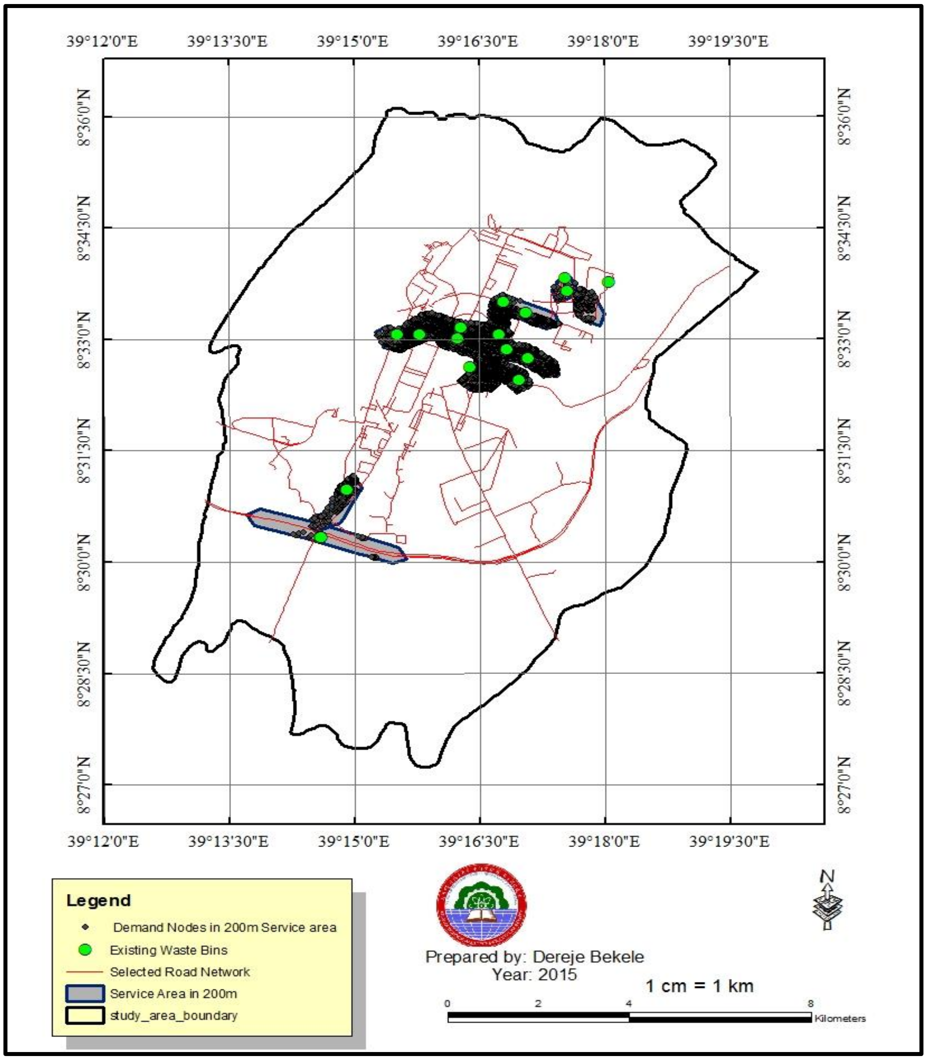

Figure 4.9: Existing waste bins service coverage in 200m distance

Scenario two: 300m trimming distance for existing waste bins

This scenario demonstrates that about 12,395 or 18.38% of the waste generating nodes are served. This is resulted from inadequate number and unequal distribution of the existing waste bin locations and causes for 55,060 or 81.62% of the waste generating nodes to be out of the service domain. This implies that the northwestern, southeastern and small parts of southwestern of the town are not served from the existing waste bin. Accordingly, due to the demand nodes are un-covered with the service area polygon; the un-served demand nodes dispose their waste in the nearby road sides and a flood plain course that is a cause for environmental pollution as well reduces the beauty of the town at large (Figure 4.10).

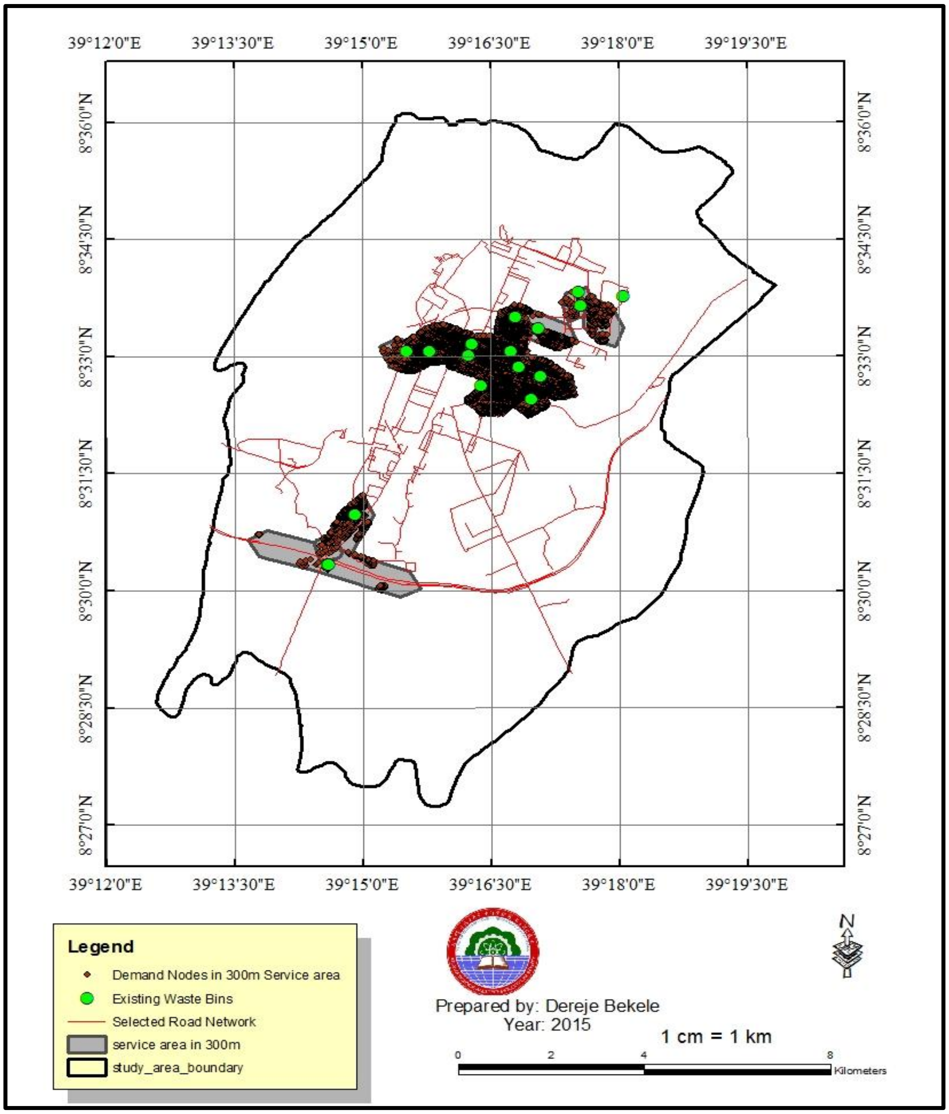

Figure 4.10: Existing waste bins service coverage in 300m distance

Scenario three: 400m trimming distance for existing waste bins

This scenario shows that about 15,409 or 22.84% of the waste generating nodes are served in the town. Moreover, the unequal distribution, inadequate number and unscientific allocation of the existing waste bin locations are starting point for 52,046 or 77.16% of waste generating nodes to be out of the service domain. This causes that the southeastern parts of the town are not served from the existing waste bins (Figure 4.11). The un-served 77.16% demand nodes did not use the waste bins because of longer distance to dispose their waste. *Kebele* 01 have large amount of waste generation and yet with poor facility service area coverage. The frequency of the truck to lift the SW bins is maximum, (15 times in a month, in *kebele* 01, 11 and 14).

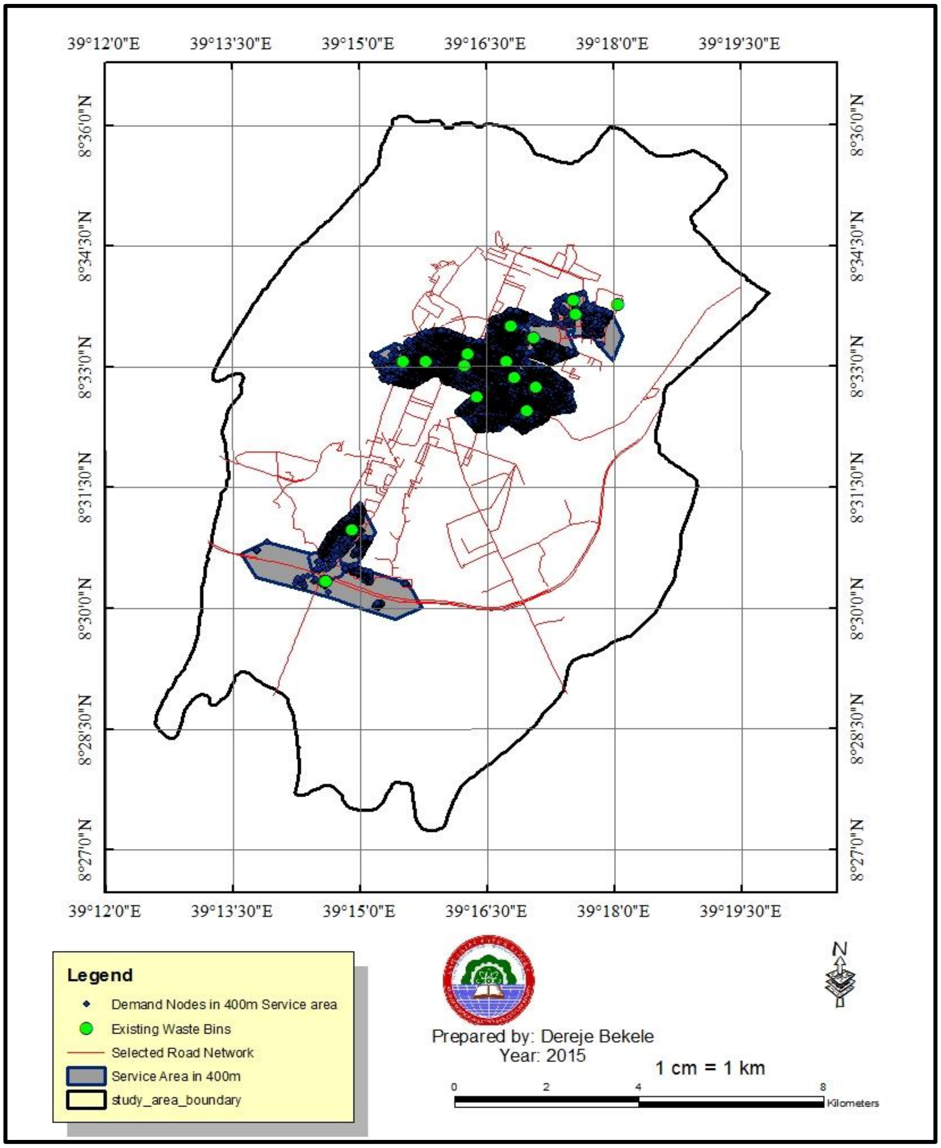

Figure 4.11: Existing waste bins service coverage in 400m distance

Scenario four: 500m trimming distance for existing waste bins

Scenario four shows that about 18,258 or 27.07% of the waste generating nodes are served in the town. 49,197 or 72.93% of waste generating nodes are out of the service domain. This implies that the Northwestern and Southeastern parts of the towns are not served at all from the existing waste bin (Figure 4.12). Consequently, due to the unevenly distributed SW bins and longer traveling distance to the bins, the un-served demand nodes may not use the existing facilities. The frequency for the tack route is high in *kebele* 12 since the size the waste generated is not accommodated with the existing facilities. Besides, this scenario is selected to be one of the service area analyses results that encompass more than 27.07% of the waste generating nodes in the town (Figure 4.12).

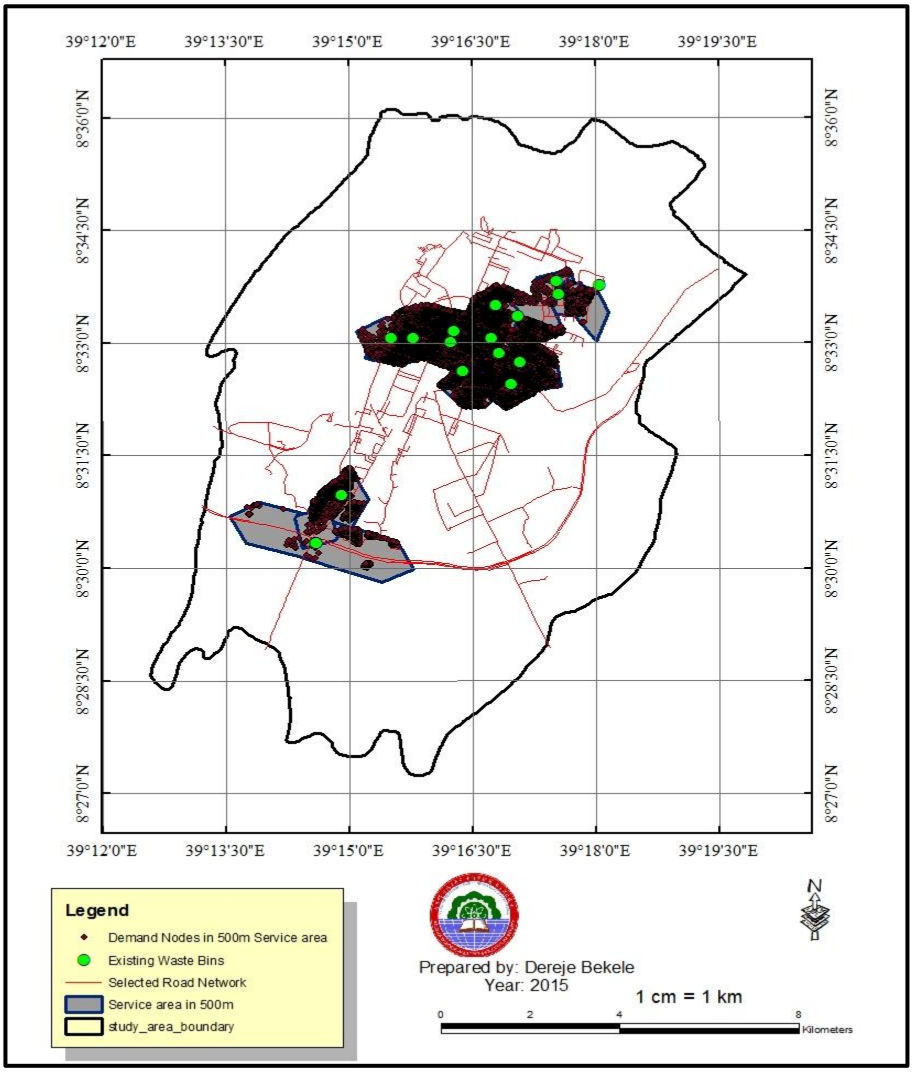

Figure 4.12: Existing waste bins service coverage in 500m distance

Scenario five: 200m trimming distance for proposed waste bins

Scenario five shows that about 40,961 or 60.72% of the waste generating nodes are served and due to the shorter trimming distance polygon, about 26,455 or 39.28% of waste generating nodes are being out of the service domain. This implies that the some parts of northeast and southwest of the town are not served all from the proposed waste bin. Therefore, the un-served demand nodes, which are out of the service area analysis dispose their waste illegally on the roadsides and streams that is a challenge for SWMS. (Figure 4.13).

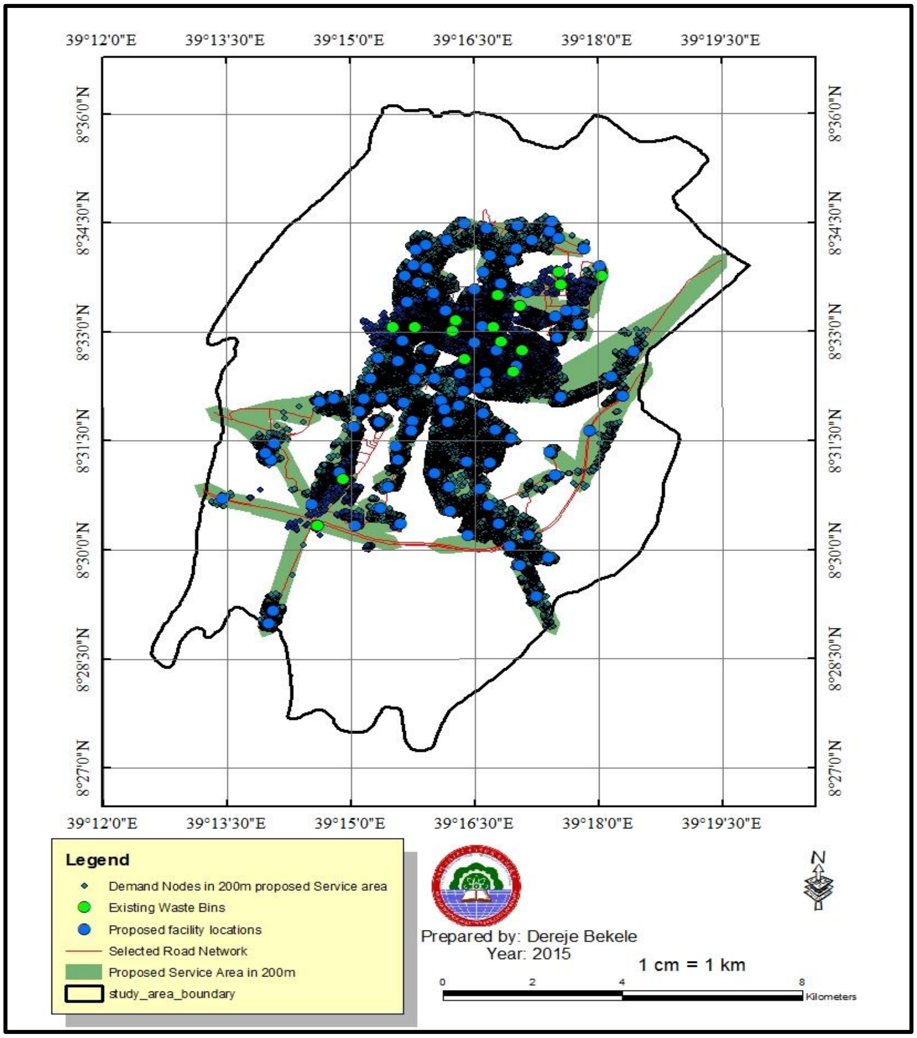

Figure 4.13: Proposed waste bins service coverage in 200m distance

Scenario six: 300m trimming distance for proposed waste bins

Scenario six illustrates that more than 55,078 or 81.65% of the waste generating nodes are served in the town. In this case, the proposed waste bin locations are distributed based on the demand nodes and road network and as a result only for 12,455 or 18.35 % of waste generating nodes to be out of the service domain. This causes that almost all the demand nodes are served from the proposed solid waste bins (Figure 4.14). Additionally, this scenario is selected to be one of the service area analyses results that encompass more than 82% of the waste generating nodes in the town.

Waste generation is maximum in in *kebele* 01 and minimum in *kebele* 06 this is because of the waste generation is directly proportional to the number of demand nodes or population size (See figure 3.3). *Kebele* 09 has a minimum and *kebele* 07 has a maximum time interval to fill the bins. The road length in *kebele* 01 and 12 are maximum and is minimum in *kebele* 6, which is used for placing the SW bins (Table 4.14). Consequently, *kebele* 09 part of the town is faced with large amount of waste generation and yet with poor facility service area coverage due to poor waste bins sharing capacity (Figure 4.14).

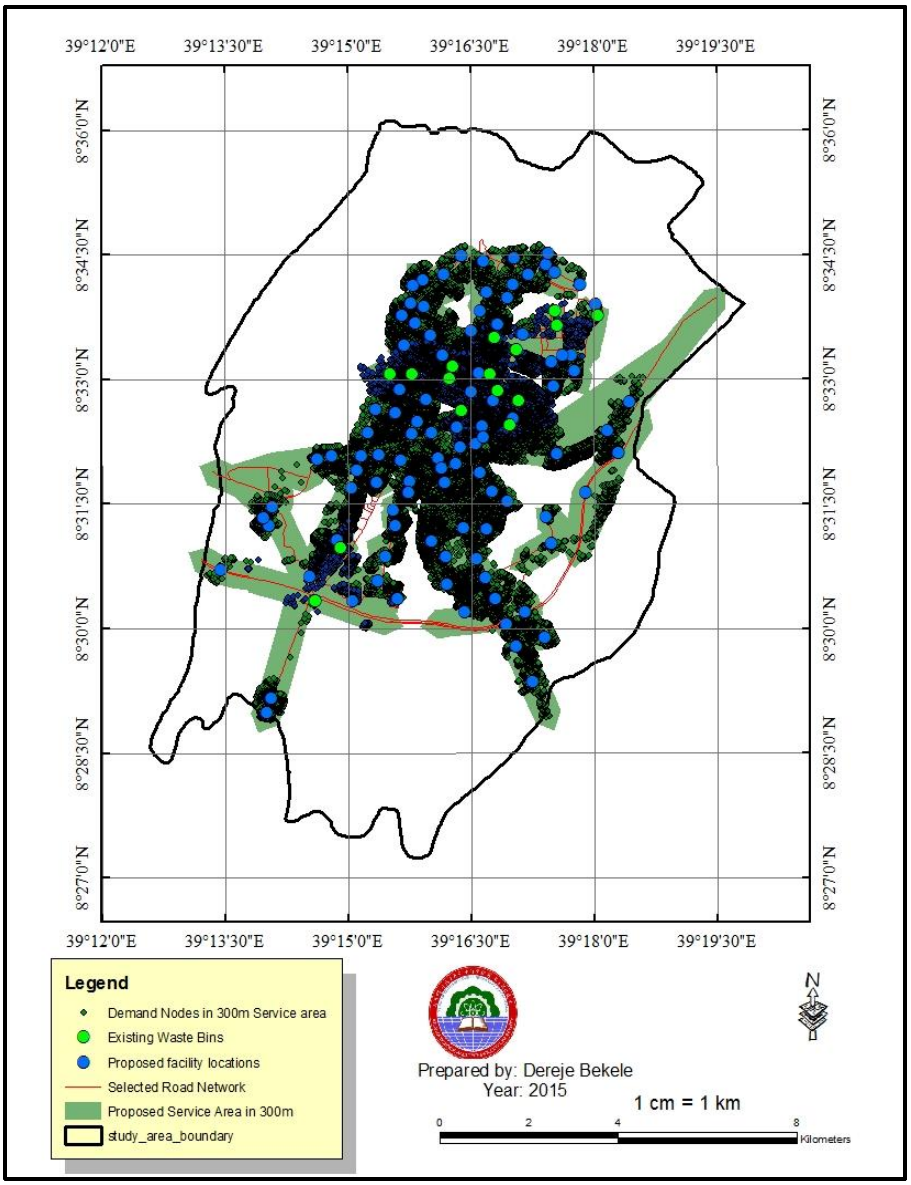

Figure 4.14: Proposed waste bins service coverage in 300m distance

Scenario seven: 400m trimming distance for proposed waste bins

Scenario seven indicates that more than 60,805 (90.14%) of the waste generating nodes are served in the town. There are 6,650 (9.86%) of waste generating nodes being out of the service domain. Therefore, due to the longer traveling distance to the bins, demand nodes may dispose their waste illegally that create environmental pollution as well reduce the beauty of the town at large. As a result, the maximum and minimum waste generation is observed in *kebele* 01 and 06 respectively. On the other hand the frequency for the track in the proposed waste bin is high in *kebele* 09 three trips per month, is minimum in *kebele* 07 two trips per month in the town. Moreover, this scenario is selected to be one of the service area analyses results that encompass more than 90% of the waste generating nodes in the town (Figure 4.15).

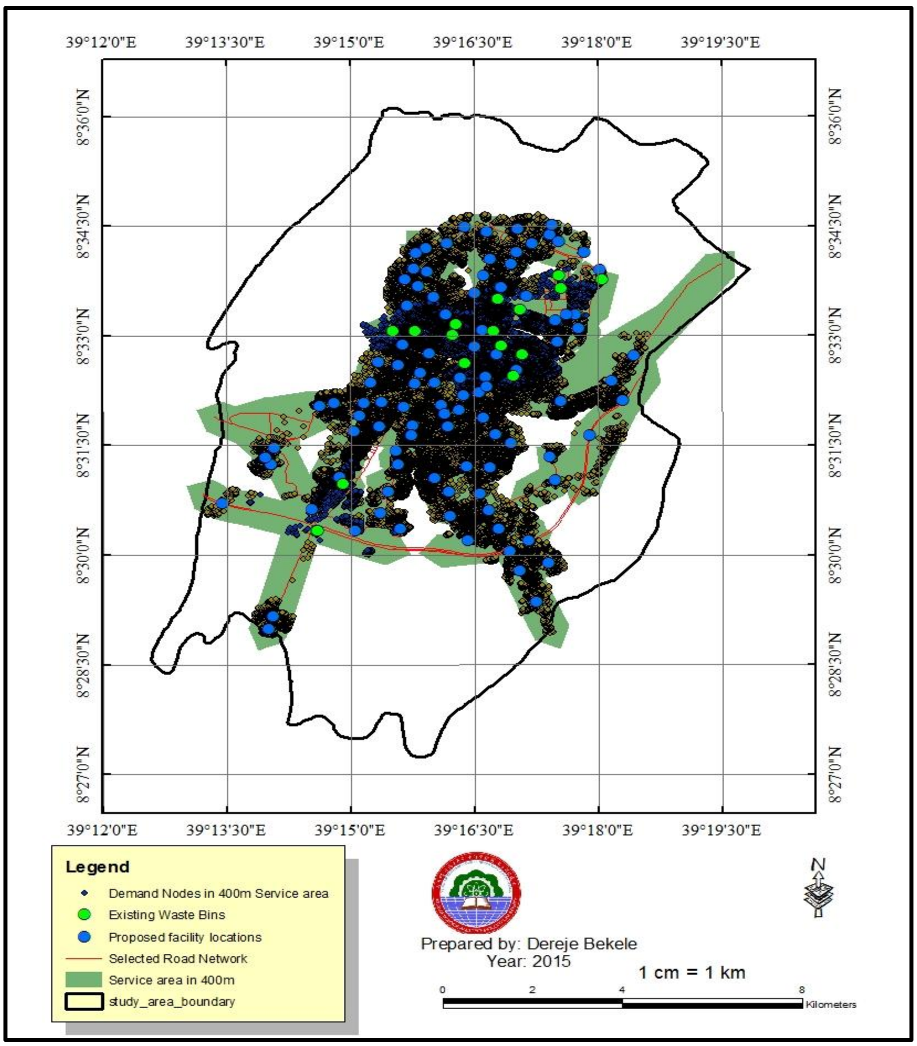

Figure 4.15: Proposed waste bins service coverage in 400m distance

Scenario eight: 500meter distance for proposed waste bins

Scenario eight indicates that more than 63,856 (94.66%) of the waste generating nodes are served in the town. This implies that almost all parts of the town except newly settled area of having road network problems are served at all from the proposed waste bin (Figure 4.16). Thus, the maximum and minimum waste generation observed in *kebele* 01 and *kebele* 06, maximum and minimum time interval in *kebele* 07 and *kebele* 09 and maximum and minimum frequency in *kebele* 09 and *kebele* 07 in other *kebeles* respectively. As a result, *kebele* 09 in the town is faced with large amount of waste generation and yet with poor facility sharing capacity.

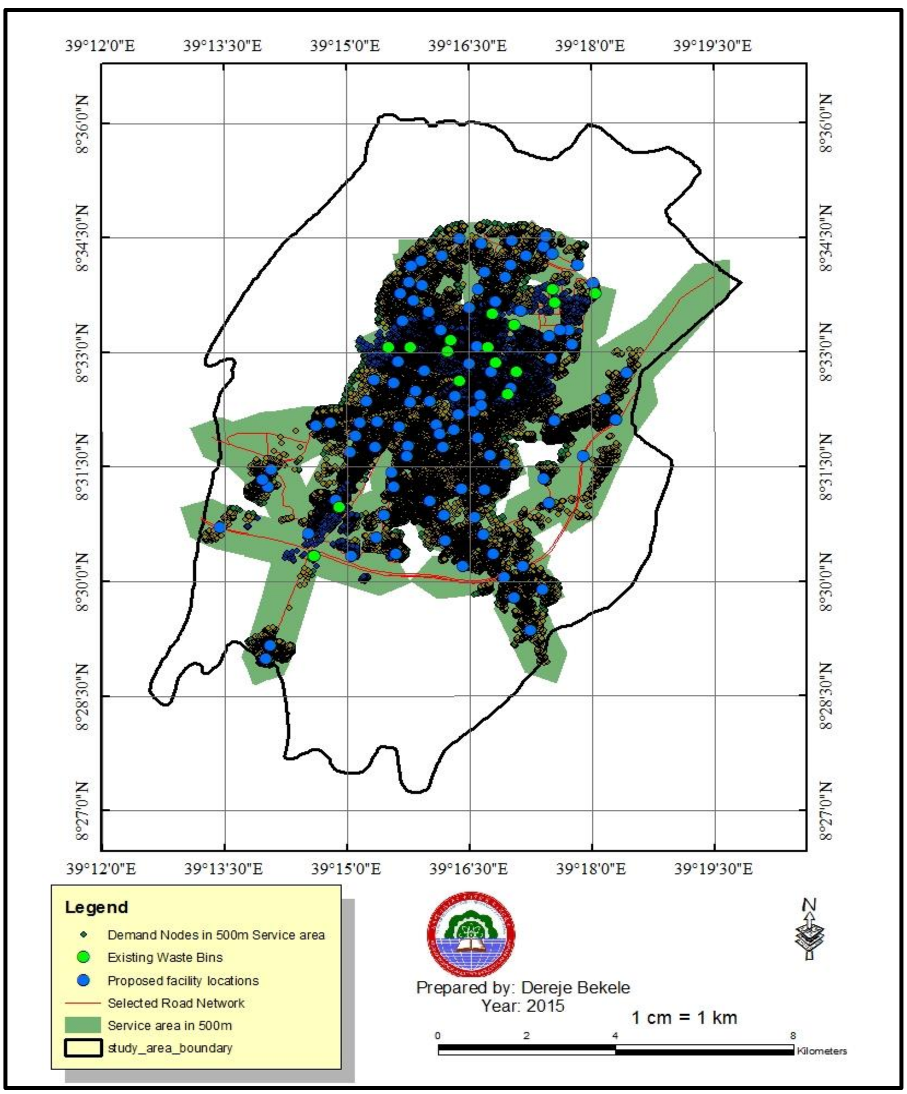

Figure 4.16: Proposed waste bins service coverage in 500m distance

4.2.4 Summary of Service Area Analysis

In Adama Town there are 68,369 demand nodes among these 914 nodes are non-waste generating and 67,455 demand nodes are waste generating nodes. Based on the proposed walking distance values (200, 300, 400, and 500 meter) service area analyses were carried out using the 117 proposed waste bins or supply node locations. According to Asfaw (2007) and Fatima (2008) the acceptable walking distance ranges from 100 to 200 meters from waste generating point to the dumping site point location of SW bins. But the researcher modifies the walking distance standards in order to include the area having scattered population and road network problems. Consequently, 45,598 or 67.59% the demand nodes on average are served from the proposed SW bins (Table 4.2 and 4.3)

On the other hand almost all the waste generating demand nodes were served 63,856 (94.66%) taking heed of the 500 meter proposed facilities location where as 18,258 (27.07%) of the demand nodes were served in the existing solid waste bins. This indicates that the accessibility level of the existing facilities is very far from the requirements of the dwellers in the town. The following table (Table 4.2 and Table 4.3) was used to summarize the served and un-served demand nodes.

Table 4.2: Service Area Analysis of Existing Waste Bins

Service Area Analysis	Number of Served nodes	Number of Un-Served nodes	Percentage of un- served nodes	Percentage of served nodes
200m	8930	58525	86.76	13.24
300m	12395	55060	81.62	18.38
400m	15409	52046	77.16	22.84
500m	18258	49197	72.93	27.07

Table 4.3: Service Area Analysis of Proposed Waste Bins

Service Area Analysis	Number of Served nodes	Number of Un-Served nodes	Percentage of un- served nodes	Percentage of served nodes
200m	40961	26494	39.28	60.72
300m	55078	12377	18.35	81.65
400m	60805	6650	9.86	90.14
500m	63856	3599	5.34	94.66

4.3 Results

4.3.1 Waste Bin Locational analysis

The road network is important to travel the residences from the demand nodes to the facilities location and tracks travel the filled bins from transfer station to disposal site. In Adama Town, there is a road network of total length 672.25 km of different width (8m, 10m, 12m, 15m, 20m, 30m and 40m). Among the existing road network, the road width greeter or equal to 15m width or road type one and road type two (15m, 20m, 30m, and 40m) was selected from the all digitized road network of the town for placing the facilities. The non-waste generating land use like Green areas and public services like hospitals do not contribute solid waste because they have their own solid waste bins.

The existing facilities are serving for 23% to 27% (Table 4.3) of the waste generating nodes at a walking distance of 400m to 500m respectively and these bins were located randomly without considering the waste generated, the road condition and the distance traveled to the bins. According to some surveys estimation, a household should get a container within 200 meters of his vicinity Yami Birke (1999) and one container provides services to a maximum of 2000 people. However, the present facility serves for more than 2,739 demand node or 17,879 people shared a single solid waste collection bins, which is 8 times higher than recommend by NUPI (one collection bins for 2000).

4.3.2 Waste generation, time interval, frequency and replacement schedule

Waste generation is directly related with the population size or number of demand nodes. On this basis the number of the demand nodes in *kebele* 01 is maximum that is more than 16.08% of the total waste generating node is in *kebele* 01. On the other hand the number of the demand nodes in *kebele* 06 is minimum that is less than 1.09% of the waste generating demand nodes (Table 4.4). This implies that the waste generation in *kebele* 01 is a maximum and is a minimum in *kebele* 06 in both existing and proposed waste bins cases. Therefore, to minimize the overflow of the solid waste which may bring environmental pollution proportional number and location of solid waste bins should be placed.

Table 4.4: Summary of WG nodes and proposed facilities in Adama Town at kebele level

kebele	**Number of WG demand**	***Kebeles* WG in %**	**Number of Facilities**
01	10265	16.08	20
02	6823	10.69	13
03	3576	5.6	6
04	1028	1.61	2
05	2518	3.94	5
06	696	1.09	1
07	944	1.48	2
08	1486	2.33	3
09	1563	2.45	2
10	5353	8.38	8
11	4545	7.12	8
12	8865	13.88	17
13	7990	12.51	14
14	8204	12.85	16
Total	**63856**	**100**	**117**

The time interval is the duration for a waste bin to be filled with in a month. It depends on the waste generation and the number of facilities in each *kebele*. It is difficult to compare the maximum and minimum time interval of the existing solid waste collection bins at *kebele* level because there are *kebeles* that have no solid waste collection bins but from those of *kebeles* having solid waste collection bins 01 and 07 *kebele* have minimum time interval, the rationale behind is the number of the waste bins is not matching with the waste generated in those kebele because they have only one solid waste collection bin and relatively 04 *kebele* have maximum time interval because it have five solid waste collection bins facilities.

On the other hand, the time interval for the proposed waste bin is maximum (19 days) in *kebele* 07. This is because the waste generating demand node or parcel node is small (472) in this *kebele,* this implies that the number of days to fill the bin takes more days and is minimum in *kebele* 09 it takes few days (12 days) because the waste generating demand node is large (782) (Table 4.5 below).

Table 4.5: Time interval (number of days required to fill the waste bins) at kebele level

kebele	**Accessible DN**	**N$^{\underline{0}}$ of Facilities**	**DN shared to all bins**	**Time Interval (T)**	
				Days	**months**
01	10265	20	513	18	1
02	6823	13	525	17	1
03	3576	6	596	15	1
04	1028	2	514	18	1
05	2518	5	504	18	1
06	696	1	696	13	1
07	944	2	472	19	1
08	1486	3	495	18	1
09	1563	2	782	12	1
10	5353	8	669	14	1
11	4545	8	568	16	1
12	8865	17	522	18	1
13	7990	14	571	16	1
14	8204	16	513	18	1
Total	**63856**	**117**	**7940**	**230**	**14**

The frequency can be defined as the number of times for the track to lift the filled waste bin and inversely related with time interval. From the point view of existing waste bins like time interval it is difficult to compare frequency at a *kebele* level since some *kebeles* have no SW bins facility but from those having SW bins *kebele* 01 and 07 has a maximum frequency (15times) because those *kebeles* have minimum time interval (2days). This causes that more transportation cost will be earned and environmental risk due to higher frequency in those *kebele*. On the other hand, *kebele* 04 has a minimum frequency (4times) this implies that number of days required to fill the waste bins is high (5days). The frequency for the track in the proposed waste bin is high in *kebele* 09 (3times) per month and (2times) in all other *kebeles* per month (Table 4.6 below).

Table 4.6: Frequency (number of days/month for the track to lift the bins) at kebele level

Kebele	**Accessible Demand Nodes**	**Time interval (T) in days**	**Frequency (F)**
01	10265	18	2
02	6823	17	2
03	3576	15	2
04	1028	18	2
05	2518	18	2
06	696	13	2
07	944	19	2
08	1486	18	2
09	1563	12	3
10	5353	14	2
11	4545	16	2
12	8865	18	2
13	7990	16	2
14	8204	18	2
Total	**63856**	**230**	**29**

Replacement Schedules can be defined as the time table for the track to lift the filled waste bins to disposal site per week and direct relationships with frequency.

Table 4.7: Replacement Schedules of SW Collection Bins of Adama Town at Kebele level

Kebele	**Accessible DN**	**Time interval (T)**	**Frequency (F)**	**Replacement schedule of bins**			
				W1	**W2**	**W3**	**W4**
01	10265	18	2	0	0	1	1
02	6823	17	2	0	0	1	1
03	3576	15	2	0	1	0	1
04	1028	18	2	0	0	1	1
05	2518	18	2	0	0	1	1
06	696	13	2	0	1	0	1
07	944	19	2	0	0	1	1
08	1486	18	2	0	0	1	1
09	1563	12	3	0	1	1	1
10	5353	14	2	0	1	0	1
11	4545	16	2	0	1	0	1
12	8865	18	2	0	0	1	1
13	7990	16	2	0	1	0	1
14	8204	18	2	0	0	1	1
Total	**63856**	**230**	**29**	**0**	**6**	**9**	**14**

Solid waste bins replacement is maximum (3times per week) in *kebele* 09 and (2times per week) in all other *kebeles* in proposed solid waste scenarios. This implies that the proposed solid waste scenarios have environmental advantage by reducing co_2 emission and economical advantage by reducing fuel conception.

4.4 Discussion

4.4.1 Accessible and Inaccessible Nodes

Resident's need the location of SW bins at an acceptable walking distance 100-200 meter (Fatima, 2008). In the same talking from the key informat interview the optimum distance from demand node waste bins should be 200-300m (Annex-3) but since there is a problem of settlements and road network at some parts of the study area it is difficult to cover high percentages of demand nodes. Node accessibility and walking distance have direct relationships that means as distance increases node accessibility increases but inaccessibility decreases for both existing and proposed S bins. Due to this facts the researcher decide the walking distance one step forward from the standards in order to cover the area having settlement and road network problem because as the walking distance from the SW bins increases they gets opportunities to be enclosed within Service Area (Table 4.8 & 4.9).

Table 4.8: walking distance vs. node accessibility relationships for existing waste bins

Distance	**Accessible nodes**	**Inaccessible nodes**	**Node accessibility Change rate**	**Range(max.-min.)**
200m-300m	(13.24-18.38)%	(86.76-81.62)%	5.14%	27.07% - 13.24% = **13.83%**
300m-400m	(18.38-22.84)%	(81.62-77.16)%	4.46%	
400m-500m	(27.07-22.84)%	(77.16-72.93)%	4.23%	

Table 4:9 walking distance vs. node accessibility relationships for proposed waste bins

Distance	**Accessible nodes**	**Inaccessible nodes**	**Node accessibility Change rate**	**Range(max. -min.)**
200m-300m	(60.72-81.65)%	(39.28-18.35)%	20.93%	94.66% - 60.72% = **33.94%**
300m-400m	(81.65-90.14)%	(18.35-9.86)%	8.49%	
400m-500m	(90.14-94.66)%	(9.86-5.34)%	4.52%	

4.4.2 Comparison of the Existing and Proposed waste bins scenarios

The waste generation rate is the same in both existing and proposed waste bins. Service coverage of existing waste bins is poor only about 27.07% of demand nodes served but, the service coverage of proposed waste bins is very good that about 94.66% of waste generating nodes served and the solid waste holding capacity at a time of the existing waste bins is very low (160$m^{3)}$ in comparison to the generated waste and the proposed waste bin holding capacity at a time is optimum (936m^3). The time interval for the existing SW bins is smaller than the proposed waste bins (2days) but high frequency (15times). The time interval for the proposed SW bins is high (19 days) but Low frequency (2times)/month. This implies that the frequency of the existing SW bins is higher than the proposed ones due to the optimum number and location of the waste bins in proposed waste bins scenarios (Table 4.10 below).

Table 4.10: Comparison between the existing and proposed waste bins scenarios

		Existing waste bins	Proposed waste bins	Difference
Service Coverage of scenarios to ward both existing and proposed waste bins	Scenario 1	13.24%	60.72%	47.48%
	Scenario 2	18.38%	81.65%	63.27%
	Scenario 3	22.84%	90.14%	67.30%
	Scenario 4	27.07%	94.66%	67.59%
Optimum SW holding capacity at a time	160m^3		936m^3	776m^3
WBs/people ratio	One waste bins to 17,879people		One waste bins to 3,056 people	14,823
Time interval	Low time interval (2days)		High time interval (19 days)	17days
Frequency	High frequency (15times)		Low frequency(2times)/month	13times

4.4.3 Proximity of solid waste bins

To reach the existing SW bins dwellers was traveling longer distances, for example the solid waste collection bins in *Kebele* 01, 07 and 11 are located apart more than 1000 meters from the *kebeles* having solid waste collection bins (Annex-3) and Some *kebeles* do not have solid waste collection bins at all (Annex-1). This condition forces the demand nodes above 500m walking distance to dump their waste in their nearby open areas, roadsides and drainage channels. It is known that the proximity level of SW bins should be in a walking distance. According to Ahmed (2007) the distance from demand nodes to the facilities is prefer to be nearer so it is advisable to provide a bin within a reach of 100 meters for all the dwellers.

As noted by Lemma (2007) from questionnaire survey of 162 households only 21.6 % are within the radius of 100 meters, 26.5% are found in between 100-200 meters. The rest 32.7% of the households have to move more than 500 meters to reach the container. Even there are families (6.8%) who do not know where the container is located. Of course there are different distances required for the placement of containers. Location of SW bins has direct impact on SWM service but, placement of containers 200 meters away from residential areas is usually recommended by the municipality. Due to this fact, the preference of the dwellers to dump their waste in their nearest SW bins increases that have paramount importance in safe solid waste management practices.

Accordingly, more than 94.66% of the waste generating demand nodes in the town are accessible to the waste bin proposed locations from walking distance range point of view. The study conducted by (Tesfaye, 2011) in Arada Sub City at traveling distance or trim polygon of 100m, 200m, 300m and 410m shows that the accessibility is greater than 97% for the proposed SW bin because Addis Ababa have better population settlement and road network than Adama.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

It is concluded that GIS is a powerful tool to manage spatial data for the reason that it has a great facility for geographic features and their attributes in a computer database. GIS is also keys to evaluate urban waste bins facilities planning through providing spatial relational information. Municipal facility planning have naturally spatial dimension and this is the most compelling evidence that GIS is exceling in assessing the arrangement of urban services. The advantage of using a GIS for the locational analysis of Adama Town waste bins facilities helped the identification of the accessible and inaccessible demand nodes through pointing areas require attention, visual cross checking with statistical data, and provide a platform for presenting the analysis on map in a way that government officials can review their plan.

Effective solid waste collection is a vital component of public service provisions. The failure of this service can result in many kinds of unfavorable outcomes in the long run, which may have serious adverse effects on public health and the environment and 27.07% of waste generating demand node served with the existing bins. So problem arises when 72.93% of un-served demand nodes illegally dumping their waste that causes various environmental and public health problem. To improve this solid waste collection system demand node location and service area of bins can be calculated accurately using Network Analysis function in GIS software and optimum number of collection bins computed using SW generated from demand nodes in the study area.

The 500 meter trimming distance for proposed collection bins location is optimum for equitable services since more than 94.6% SW generating demand nodes are in service area domain with respect to the above trimming distance and no existing collection bins location is optimum within specified distance since less than 28% of the demand nodes in the existing collection bins location are in service area domain with respect to trimming distance and 100 waste bins new locations and 17 waste bins existing locations with the total of 117 waste bins are optimum number.

The time interval is low, two days and frequency is high, that is fifteen times in a month for the existing solid waste collection bins. In contrast, the proposed ones have higher time interval, 19 days and lower frequency that are two times in a month. This indicates that the existing solid waste collection system is economically cost, methodologically tedious and environmentally risk due to higher frequency for the track to lift the filled waste bins to the disposal sites.

The accessibility for the existing solid waste collection bins is less than 28% and is greater than 94.6% for the proposed solid waste collection bins. This implies that the proposed solid waste collection bins location is more than three times accessible than the existing solid waste collection bins. Settlement and road network problems are the major limitations that make 5% of waste generating demand node out of the service coverage.

5.2 Recommendation

Based on the findings researcher recommended as follow:

- GIS is a powerful tool that gives an opportunity to update Geospatial data at any time. Therefore, to automate Adama Town solid waste management system, the Sanitation and Greenery work process offices can use GIS technique for better solid waste management and planning.

- Adama Town Administration should make a decision to increase the number of solid waste bins to 117 and distribute at 500 meter distances from households for better demand node coverage in Adama Town.

- Sanitation and Greenery work process offices should consider and take heed of the time interval to fill and the frequency to replace waste bins to provide base line information for planning and managing the solid waste management practices in an effective ways.

- Further study based on the seasonal variation will be important to compute time interval and frequency that gives better replacement schedule of solid waste bins in the study area.

In general, Adama Town Administration, Sanitation and Greenery work process bureau, Adama Town Transport Bureau, Adama Town Land development and Management Bureau, *Kebele* officials and many other related stakeholders must work together to see the Clean and Green Adama.

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Annexes

Annex 1: Distribution of $8m^3$ Solid Waste Collection Bins in Adama Town

***Kebele* Name**	**Nº of waste bins**	**Average family size**	**Total population**
01	1	5.59	26220
02	-	5.59	18731
03	-	5.59	27362
04	5	5.59	27906
05	3	5.59	26345
06	-	5.59	9707
07	1	5.59	16014
08	-	5.59	15121
09	4	5.59	30353
10	-	5.59	24570
11	2	5.59	25817
12	-	5.59	14764
13	-	5.59	15001
14	4	5.59	28920
Total	20	5.59	306831

Source: Sanitation and Greenery Work Process office and (CSA, 2015)

Annex 2: Location of Existing Waste Bins Collected by GPS in Adama Town

S/No	**Kebele**	**Codes of SW bins**	**Easting**	**Northing**
1	04	SW01	530701	945147
2	09	SW02	527343	941294
3	09	SW03	526778	940120
4	09	SW04	526763	940117
5	09	SW05	528118	942197
6	14	SW06	532137	946549
7	14	SW07	532197	946227
8	01	SW08	530009	946279
9	04	SW09	529867	945321
10	05	SW10	528950	945389
11	05	SW11	528958	945135
12	05	SW12	528454	945143
13	11	SW13	531123	944007
14	07	SW14	529786	945055
15	04	SW15	533088	946450
16	14	SW16	530865	944769
17	04	SW17	531279	945697
18	04	SW18	530793	945966
19	11	SW19	530061	944324
20	14	SW20	531337	944548

Source: Collected by researcher starting from July 05/07-12/07/2014

Annex 3: Key Informat Interview

Interviewee: Mr. Kokebe

Interview time starting from 8:00 AM to 9:30 AM on the date of 28th June 2014 at Adama Town Administration office

Designation: “*GIS based analysis of the Location of collection bins for municipal solid waste management system in Adama Town”*

Interviewer: Dereje Bekele

Q1. What are the methods for waste collection?

Answer. Generally there are three methods which are in practice,

a) Road sweeping is done daily

b) Door to door garbage collection.

c) Public dumping i.e. citizens throws waste in the bins on their own.

Q3.How is the waste carried to the bins from the different sources?

Answer. The swept waste and the door to door collected waste are carried in hand carts to the waste bins.

Answer. In all there are 8 vehicles which include trucks, tempos and auto rickshaws.

Q6. How much waste is collected per day?

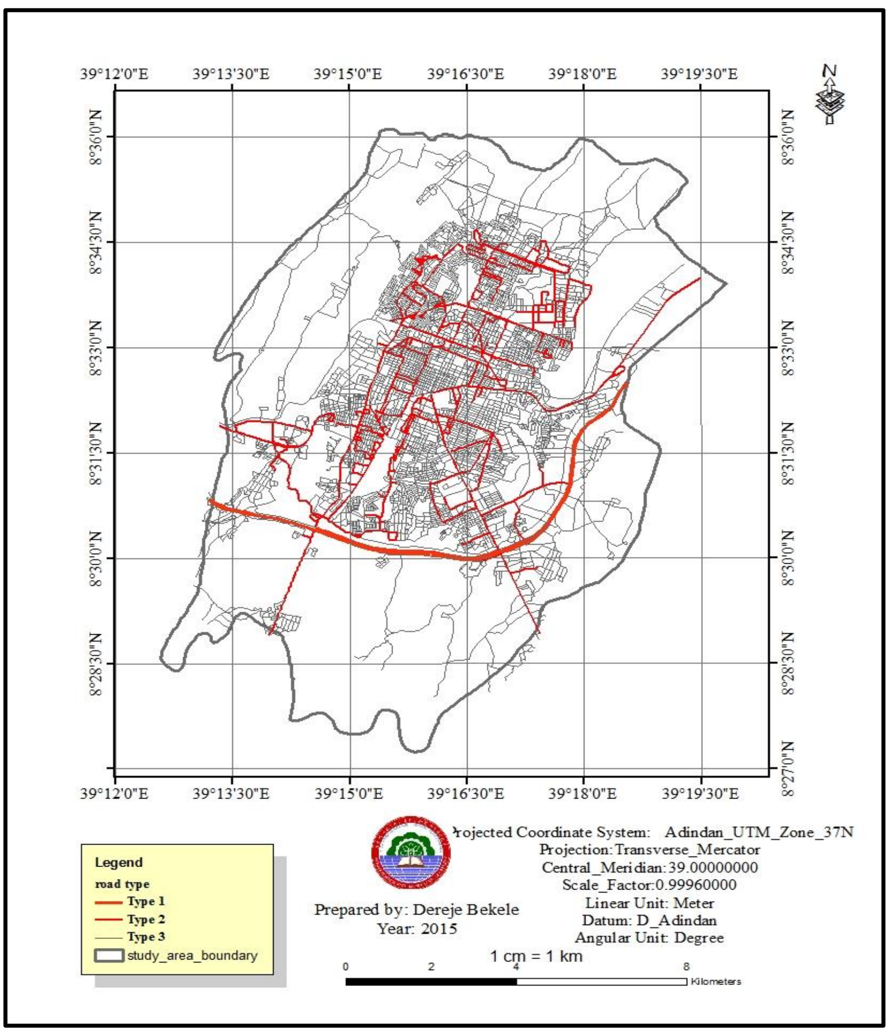
Answer. On an average 252 to 260 m^3 per day (93240 to 96200Kg/day)

Annex 4: Spatial database, type of data and corresponding geometry

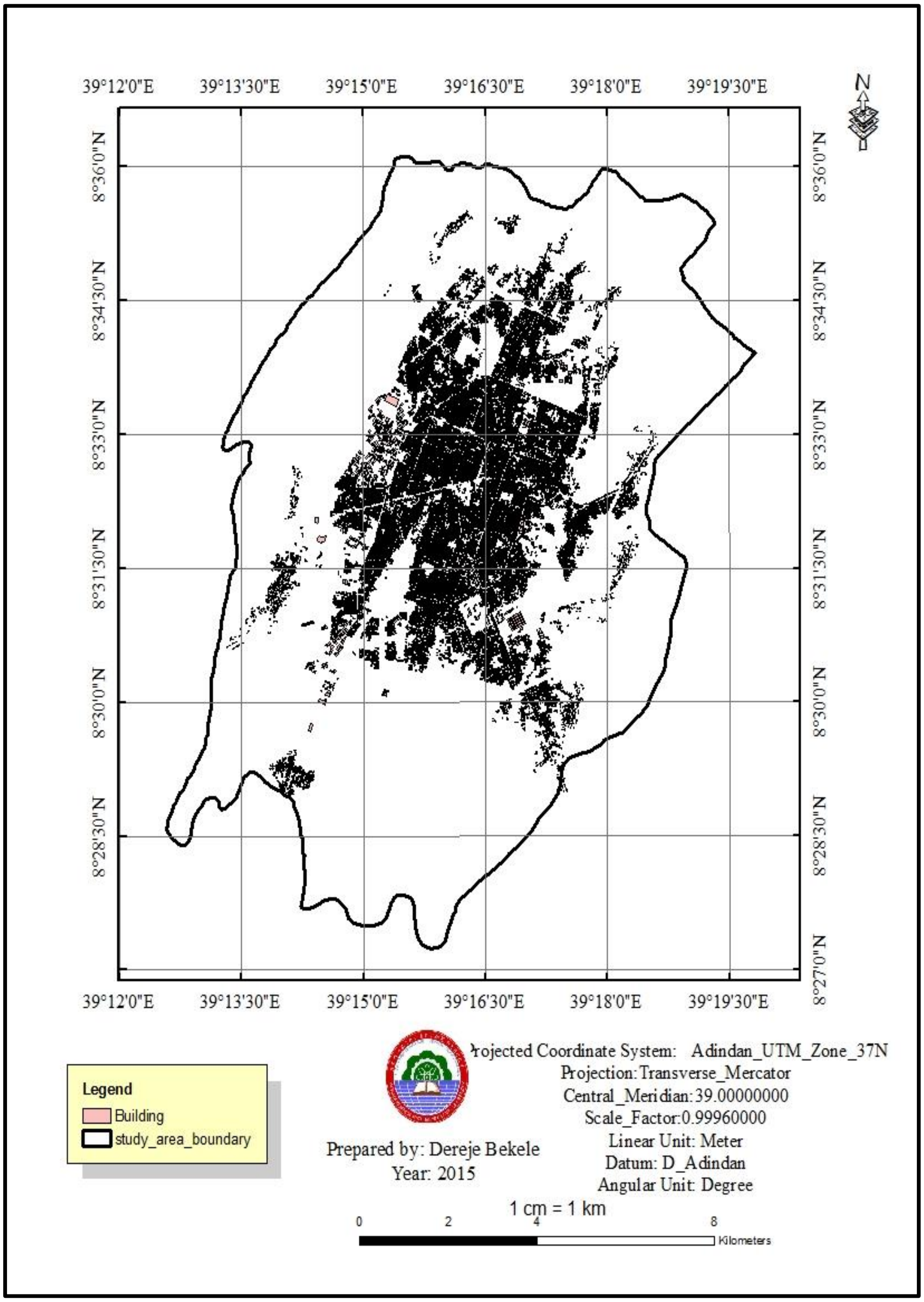
Spatial Data	Type	Geometry
Road network	Vector	Line
Waste bins	Vector	Point
Urban plan / parcels	Vector	Polygon
Existing routes	Vector	Line
Waste bins’ attributes	Tabular	-
Population data	Tabular	(join with parcels)
Land use data	Vector	-

Annex 5: Adama Town aerial photograph at pe-processing stage

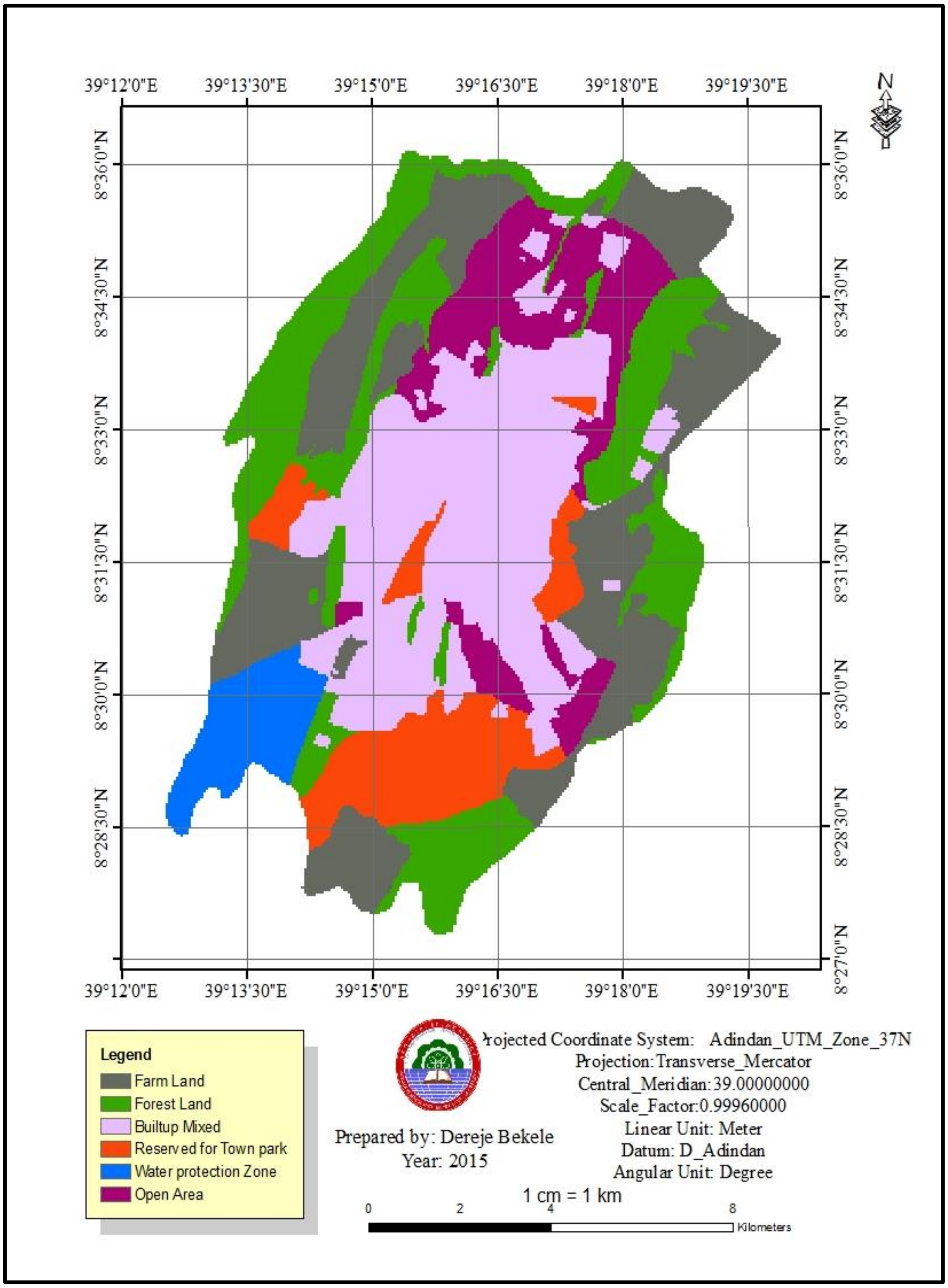
Annex 6: Road Network of Adama Town



Annex 7: Cadastral Map of Adama Town



Annex 8: Land Use Land Cover Map of Adama Town



Annex 9: Solid Waste Bins Replacement Schedule of Adama Town

Code	No of Accessible DN	WB Capacity (m^3)	WGR (kg/head/day)	Density (kg/m^3)	Time Interval (day)	No of Days in a Month	Frequency	Month Time Interval	Month 1			
									1w	2w	3w	4w
SW01	162	8	0.35	400	56	30	1	2	0	0	0	1
SW02	292	8	0.35	400	31	30	1	1	0	0	0	1
SW03	389	8	0.35	400	24	30	1	1	0	0	1	0
SW04	491	8	0.35	400	19	30	2	1	0	0	1	0
SW05	226	8	0.35	400	40	30	1	2	0	1	0	0
SW06	159	8	0.35	400	58	30	1	2	0	0	1	0
SW07	703	8	0.35	400	13	30	2	1	0	1	0	1
SW08	820	8	0.35	400	11	30	3	1	0	1	1	0
SW09	630	8	0.35	400	15	30	2	1	0	1	0	1
SW10	944	8	0.35	400	10	30	3	1	0	1	1	1
SW11	536	8	0.35	400	17	30	2	1	0	0	1	0
SW12	230	8	0.35	400	40	30	1	2	0	1	0	0
SW13	381	8	0.35	400	24	30	1	1	0	0	1	0
SW14	646	8	0.35	400	14	30	2	1	0	1	0	1
SW15	677	8	0.35	400	14	30	2	1	0	1	0	1
SW16	490	8	0.35	400	19	30	2	1	0	0	1	0
SW17	573	8	0.35	400	16	30	2	1	0	1	0	0
SW18	475	8	0.35	400	19	30	2	1	0	0	1	0
SW19	719	8	0.35	400	13	30	2	1	0	1	0	1
SW20	603	8	0.35	400	15	30	2	1	0	1	0	1
SW21	673	8	0.35	400	14	30	2	1	0	1	0	1
SW22	726	8	0.35	400	13	30	2	1	0	1	0	1
SW23	498	8	0.35	400	18	30	2	1	0	0	1	0
SW24	433	8	0.35	400	21	30	1	1	0	0	1	0
SW25	350	8	0.35	400	26	30	1	1	0	0	0	1
SW26	536	8	0.35	400	17	30	2	1	0	0	1	0
SW27	670	8	0.35	400	14	30	2	1	0	1	0	1
SW28	690	8	0.35	400	13	30	2	1	0	1	0	1
SW29	667	8	0.35	400	14	30	2	1	0	1	0	1
SW30	476	8	0.35	400	19	30	2	1	0	0	1	0
SW31	330	8	0.35	400	28	30	1	1	0	0	0	1
SW32	696	8	0.35	400	13	30	2	1	0	1	0	1
SW33	583	8	0.35	400	16	30	2	1	0	1	0	0
SW34	543	8	0.35	400	17	30	2	1	0	0	1	0
SW35	598	8	0.35	400	15	30	2	1	0	1	0	1

SW36	671	8	0.35	400	14	30	2	1	0	1	0	1
SW37	730	8	0.35	400	13	30	2	1	0	1	0	1
SW38	606	8	0.35	400	15	30	2	1	0	1	0	1
SW39	673	8	0.35	400	14	30	2	1	0	1	0	1
SW40	934	8	0.35	400	10	30	3	1	0	1	1	1
SW41	656	8	0.35	400	14	30	2	1	0	1	0	1
SW42	374	8	0.35	400	24	30	1	1	0	0	1	0
SW43	497	8	0.35	400	18	30	2	1	0	0	1	0
SW44	440	8	0.35	400	21	30	1	1	0	0	1	0
SW45	543	8	0.35	400	17	30	2	1	0	0	1	0
SW46	471	8	0.35	400	19	30	2	1	0	0	1	0
SW47	377	8	0.35	400	24	30	1	1	0	0	1	0
SW48	307	8	0.35	400	30	30	1	1	0	0	0	1
SW49	693	8	0.35	400	13	30	2	1	0	1	0	1
SW50	544	8	0.35	400	17	30	2	1	0	0	1	0
SW51	589	8	0.35	400	16	30	2	1	0	1	0	0
SW52	667	8	0.35	400	14	30	2	1	0	1	0	1
SW53	679	8	0.35	400	13	30	2	1	0	1	0	1
SW54	258	8	0.35	400	35	30	1	2	1	0	0	0
SW55	474	8	0.35	400	19	30	2	1	0	0	1	0
SW56	415	8	0.35	400	22	30	1	1	0	0	1	0
SW57	465	8	0.35	400	20	30	2	1	0	0	1	0
SW58	470	8	0.35	400	19	30	2	1	0	0	1	0
SW59	705	8	0.35	400	13	30	2	1	0	1	0	1
SW60	784	8	0.35	400	12	30	3	1	0	1	1	0
SW61	539	8	0.35	400	17	30	2	1	0	0	1	0
SW62	242	8	0.35	400	38	30	1	2	1	0	0	0
SW63	446	8	0.35	400	20	30	1	1	0	0	1	0
SW64	192	8	0.35	400	48	30	1	2	0	0	1	0
SW65	914	8	0.35	400	10	30	3	1	0	1	1	1
SW66	831	8	0.35	400	11	30	3	1	0	1	1	0
SW67	348	8	0.35	400	26	30	1	1	0	0	0	1
SW68	261	8	0.35	400	35	30	1	2	1	0	0	0
SW69	664	8	0.35	400	14	30	2	1	0	1	0	1
SW70	698	8	0.35	400	13	30	2	1	0	1	0	1
SW71	674	8	0.35	400	14	30	2	1	0	1	0	1
SW72	429	8	0.35	400	21	30	1	1	0	0	1	0
SW73	650	8	0.35	400	14	30	2	1	0	1	0	1

SW74	450	8	0.35	400	20	30	1	1	0	0	1	0
SW75	594	8	0.35	400	15	30	2	1	0	1	0	1
SW76	682	8	0.35	400	13	30	2	1	0	1	0	1
SW77	592	8	0.35	400	15	30	2	1	0	1	0	1
SW78	446	8	0.35	400	20	30	1	1	0	0	1	0
SW79	420	8	0.35	400	22	30	1	1	0	0	1	0
SW80	763	8	0.35	400	12	30	3	1	0	1	1	0
SW81	760	8	0.35	400	12	30	2	1	0	1	1	0
SW82	367	8	0.35	400	25	30	1	1	0	0	0	1
SW83	533	8	0.35	400	17	30	2	1	0	0	1	0
SW84	444	8	0.35	400	21	30	1	1	0	0	1	0
SW85	374	8	0.35	400	24	30	1	1	0	0	1	0
SW86	535	8	0.35	400	17	30	2	1	0	0	1	0
SW87	526	8	0.35	400	17	30	2	1	0	0	1	0
SW88	394	8	0.35	400	23	30	1	1	0	0	1	0
SW89	721	8	0.35	400	13	30	2	1	0	1	0	1
SW90	527	8	0.35	400	17	30	2	1	0	0	1	0
SW91	443	8	0.35	400	21	30	1	1	0	0	1	0
SW92	475	8	0.35	400	19	30	2	1	0	0	1	0
SW93	677	8	0.35	400	14	30	2	1	0	1	0	1
SW94	338	8	0.35	400	27	30	1	1	0	0	0	1
SW95	541	8	0.35	400	17	30	2	1	0	0	1	0
SW96	721	8	0.35	400	13	30	2	1	0	1	0	1
SW97	564	8	0.35	400	16	30	2	1	0	1	0	0
SW98	743	8	0.35	400	12	30	2	1	0	1	1	0
SW99	750	8	0.35	400	12	30	2	1	0	1	1	0
SW100	436	8	0.35	400	21	30	1	1	0	0	1	0
SW101	543	8	0.35	400	17	30	2	1	0	0	1	0
SW102	671	8	0.35	400	14	30	2	1	0	1	0	1
SW103	760	8	0.35	400	12	30	2	1	0	1	1	0
SW104	452	8	0.35	400	20	30	1	1	0	0	1	0
SW105	500	8	0.35	400	18	30	2	1	0	0	1	0
SW106	595	8	0.35	400	15	30	2	1	0	1	0	1
SW107	366	8	0.35	400	25	30	1	1	0	0	0	1
SW108	539	8	0.35	400	17	30	2	1	0	0	1	0
SW109	571	8	0.35	400	16	30	2	1	0	1	0	0
SW110	591	8	0.35	400	15	30	2	1	0	1	0	1
SW111	316	8	0.35	400	29	30	1	1	0	0	0	1
SW112	576	8	0.35	400	16	30	2	1	0	1	0	0

SW113	468	8	0.35	400	20	30	2	1	0	0	1	0
SW114	671	8	0.35	400	14	30	2	1	0	1	0	1
SW115	736	8	0.35	400	12	30	2	1	0	1	1	0
SW116	710	8	0.35	400	13	30	2	1	0	1	1	0
SW117	382	8	0.35	400	24	30	1	1	0	0	1	0

Annex 10: Formula

1. Total Waste Generation= Population times Per Capita SW Generation
2. Density SW = $\frac{\text{waste generated (kg)}}{\text{Volume (m}^3\text{)}}$
3. Capacity of a Bin = Density of the SW times Volume of the SW bin
4. Total share of each bin = $\frac{\text{Total waste generated}}{\text{Number of waste bins}}$
5. Time interval to fill a bin = $\frac{\text{Capacity of a bin}}{\text{Total share a bin}}$
6. Frequency/month = $\frac{\text{30days}}{\text{Time interval}}$
7. Waste generation of demand node = $\frac{\text{Total waste generation}}{\text{Total number of WG demand node}}$

Source: Facility location in anticipation of future competition. Location (1998)