



Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering

Assessment of Solid Waste Collection Capacity in Addis Ababa, Ethiopia

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Water Supply and Environmental Engineering.

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Addis Ababa, Ethiopia

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ABSTRACT

Waste collection and transportation is one of the crucial functional elements of municipal solid waste management. Available information about this matter is therefore essential for successful municipal solid waste management. The main objective of this study is to assess the solid waste collection practice in Addis Ababa.

For the purpose of the study, 250 pre collector groups were selected for field survey of the primary solid waste collection. Background information was gathered using semi structured interviews with the pre collector groups and the respective cleansing management agency officers. To examine the secondary solid waste collection, field observation on the trucks and interviews with truck drivers and with waste agency officers of the city was carried out.

From the study, the productivity of primary and secondary waste collection was determined; the collection capacity of the city was estimated and factors influencing the system were identified. For primary collection, three different collection methods were identified: push cart method, pushcart–collector method and truck collection method with average productivity of 2.12 m³/ worker/day and 2.81m³/ worker/day and 4.2m³/hr respectively. For secondary waste collection, the trucks productivity were determined to be 6.29 m³/hr for container truck, 18.29 m³/hr for compactor (40 m³) and 39.7 m³/hr for compactor (80 m³).

The solid waste collection capacity was determined to be 3,192,868.8 m³/year for the primary collection and 2,579,183.22 m³/year for the secondary collection. The solid waste generation rate of the city is determined to be 4, 157469.12m³/year. This shows that, on average, only 76% of the waste generated in the city was collected by primary collectors, and 80% was collected by the secondary collectors. The result indicates that the current collection system doesn't cope with the solid waste generation rate of the city.

The role of solid waste transfer station in solid waste management is great. This study includes the basis of design and conceptual layout for a new facility of a pilot service area. This design and operational plan details the features and operational procedures for a municipal solid waste transfer station to ensure a safe, operationally efficient facility that meets the waste needs of the given service area.

Declaration

I declare that this thesis is my original work performed under the supervision of research advisor Dr. Alemtsehay G/Meskel. The work has not been presented as a thesis for a degree in any other university in Ethiopia. Where material has been used from other sources, it has been properly acknowledged / referred.

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ABBREVIATION AND ACRONYMS

CMA	Cleansing Management Agency
CSA	Central Statistics Agency
EPA	Environmental Protection Authority
FDRE	Federal Democratic Republic of Ethiopia
ILO	International Labor Organization
KA	Kebele Administration
MSW	Municipal Solid Waste
MSSE	Micro and Small Scale Enterprise
NGO	Non Governmental Organization
SBPDA	Sanitation, Beautification and Park Development Authority
SWM	Solid Waste Management

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Chapter 1 INTRODUCTION

1.1 Background

Nearly all human activities produce waste generated during the acquisition of raw materials, during refining and manufacturing process and when products are used by consumers (Sango and sackey, 2007). In early times, the disposal of wastes did not pose a significant problem, because the population was small and the amount of land available for the assimilation of wastes was large (Alemayehu, 2007). However, when cities began to be more concentrated, solid waste management (SWM) became a serious and complex issue. Higher standards of living, increasing population rate and the corresponding increasing levels of consumption pattern have resulted in an increase in the quantity and variety of waste generated and their relative negative impacts on the urban environment. Furthermore, the rapid and unregulated expansions of urban areas have aggravated urban environmental problems including waste management. Hence, the problem of urban environmental degradation is becoming a common issue in all countries (Hoornweg, 1999).

SWM is defined as the collection, transportation, processing, recycling, and disposal of solid waste materials so as to reduce their effect on health, environment and aesthetics. Municipal Solid Waste (MSW) is composed of different wastes generated by households, commercial and industrial premises, institutions such as schools, hospitals, and from public spaces such as streets, markets, public toilets, bus stops, parks, and gardens (Coffey and Coad, 2010).

Improper solid waste management leads to substantial negative environmental impacts: pollution of air, water and generation of greenhouse gases from inappropriately managed landfills. Furthermore, these problems allow the infestation of insects which spread disease thus affecting the health of human beings (David, Satterthwaite, 1999). SWM is, therefore, a critical component within urban sanitation and it is also one of the most important and resource intensive services provided by municipalities (UN-HABITAT, 2010).

The waste management in a given country is directly related to the economic, social and political status of the country. The challenge of the management is tougher for middle and lower income countries. Studies show that municipalities in developing countries spend 20-50% of their available budget on SWM and serve less than average inhabitants (Memon, 2010). They collect and manage only 30-50% of the waste generated while the rest is either burned or left to decompose in open space or is dumped in unregulated landfills-impacting

the environment negatively (Lemma, 2007). This implies that SWM is of a growing concern facing the developing countries because of its social, economic and environmental implications (Krause and Townsend, 2014).

In Addis Ababa, the capital city of Ethiopia, rapid urbanization coupled with increased urban population in the last decade brought immense pressure on municipal services, mainly in the management of the ever-increasing amounts of solid waste. Due to the insufficient waste management system in the city, the habitants suffer the site and consequences of accumulated waste piles on the streets and drains all around the city. Moreover, these piles provide a breeding ground for insects that can potentially cause the outbreak of an epidemic. They also cause a nauseating smell and are quite unpleasant to see.

Hence, by critically assessing the current solid waste collection practice in Addis Ababa, this study attempts to assess the current solid waste collection practice of the city and identify the influencing factors so as to assist in finding solutions for an improved solid waste management.

1.2 Statement of the Problem

Collection of municipal solid waste is one of the major functional elements of municipal solid waste management. The collection and transportation of solid waste make the biggest demand on municipal budgets and have the greatest impact on urban living. Of the total expenditure incurred in solid waste management, typically 70 to 80 percent is directed towards the collection and transporting of wastes.

There are only very few sources that deal at length with solid waste collection in Addis Ababa. The service provided in Addis Ababa is inadequate, with refuse generated in urban areas remaining uncollected and large areas of the city receiving no regular attention. Local authorities are becoming increasingly aware of the poor quality of service provided in most areas in terms of the quantity of solid waste collected and the environmental protection provided. There is, therefore, growing demand for the provision of an adequate and regular service to all target areas and for greater efficiency.

1.3 Objective

1.3.1 General objective

The general objective of this study is to assess the solid waste collection capacity in Addis Ababa

1.3.2 Specific objectives

- To determine the productivity of primary waste collection
- To determine the productivity of secondary waste collection
- To identify influential factors affecting the collection system

1.4 Research Questions

- What is the existing solid waste collection practice in Addis Ababa?
- What amount of waste is collected in the city by all pre collectors in one day?
- What amount of waste is collected in the city by secondary waste collectors in one day?
- Is the collection capacity influenced by specific factors?

Chapter 2 LITERATURE REVIEW

2.1 Solid Waste Definition

Solid waste refers to the range of garbage arising from animal and human activities that are discarded as unwanted and useless. Waste can be categorized based on material, such as plastic, paper, glass, and metal and organic waste. Categorization may also be based on hazard potential, including radioactive, flammable, infectious, toxic, or non toxic. Categories may also pertain to the origin of waste, such as industrial, domestic, commercial, institutional or construction and demolition (Rick, 2017).

Likewise, municipal solid waste refers to solid wastes from houses, streets and public places, shops, offices, and hospitals, which are very often the responsibility of municipal or other governmental authorities. Solid waste from industrial processes is generally not considered as municipal. However, because this waste finally ends up in the municipal waste stream, it should be taken into account when dealing with solid waste. Synonymous to solid waste are terms such as “garbage”, “trash”, “refuse” and “rubbish” (Zurbrugg, 2003).

According to Pfeffer (1992), solid waste is defined as any solid material in the material flow pattern that is rejected by society. On this note, waste is a material that no longer has a value for the first user and is therefore thrown away. Considering waste as unwanted material can also be an issue of timing, that is waste can have some value for the person or society in different circumstances (Louigueur, 2007).

2.2 Types and Sources of Solid Wastes

In order to categorize what exactly municipal solid waste constitutes, there have been different attempts of categorization based on numerous classification criteria. Some of those criteria are source from which solid waste emanates, and nature of solid waste components. On the basis of the nature of items that constitute solid wastes, it can be classified into organic or inorganic, combustible or non-combustible, and putrescible or non-putrescible (G/Tsadkan, 2002).

Knowledge of the sources and types of solid wastes, along with the data on composition and rate of generation, is basic to the design and operation of the functional elements associated with the management of solid wastes. The source of solid wastes is dependent on the socio-

economic and technological levels of the society (Monroe, 1997). Table 2-1 describes different sources and types of solid wastes.

Table 2-1: Different sources and types of solid wastes (Source; World Bank, 2012)

Source	Typical Waste Generators	Types Of Solid Waste
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes (e.g., paints, aerosols, gas tanks, waste containing mercury, motor oil, cleaning agents), e-wastes (e.g., computers, phones, TVs).
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants excluding specific process wastes if the municipality does not oversee their collection)	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes.
Commercial	Stores, hotels, restaurants, markets, office buildings	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes, e-wastes.
Institutional	Schools, hospitals (non-medical waste), prisons, government buildings, airports	Same as commercial
Construction and Demolition	New construction sites, road repair, demolition of buildings, renovation site	Wood, steel, concrete, dirt, bricks, tiles
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants	Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas, sludge
All of the above should be included as municipal solid waste. Industrial, commercial, and institutional (ICI) wastes are often grouped together and usually represent more than 50% of MSW. Construction and Demolition waste is often treated separately: if well managed it can be disposed separately. The items below are usually considered MSW if the municipality oversees their collection and disposal.		

2.3 Solid Waste Management

Solid waste management (SWM) is defined as a discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal of solid waste materials in a way that best addresses the range of public health, conservation, economics, aesthetics, engineering, and other environmental considerations (Rick, 2017).

In its scope, solid waste management includes planning, administrative, financial, engineering and legal functions involved in solutions to all problem of solid waste. The solutions may involve complex interdisciplinary relationship among such fields as political sciences, city and regional planning, geography, economics, public health, sociology, demography, communications and conservation, as well as engineering and materials science (WHO, 1999).

Solid waste management practices can differ for residential and industrial producers, for urban and rural areas, and for developed and developing. The administration of non hazardous waste in metropolitan area is the job of local government authorities. On the other hand, the management of hazardous waste materials is typically the job of the generator, subject to local, nation and even international authorities (Rick, 2017).

Solid waste management is not an isolated phenomenon that can be easily compartmentalized and solved with innovative technology or engineering. It is particularly an urban issue that is closely related, directly or indirectly to a number of issues such as urban life styles, resource consumption patterns, jobs and income levels, and other socio-economic and cultural issues. All these issues have to be brought together on a common plat form in order to ensure a long term solution to urban waste (Sandra, 1995). It is apparent that making accurate decisions about municipal SWM issues can be a complex task. Both long term and short term plan is needed to get a balance of cost effectiveness and environmental benefit (Yeuan, 2000).

As Michael, 1995 listed, if sold wastes are not managed properly, there are many negative impacts that may result. Such as;

- The open burning of waste cause air pollution; the products of composition include dioxins which are particularly hazardous
- Uncollected wastes degrade the urban environment, discouraging efforts to keep streets and open spaces in a clean and attractive condition.
- Polluted water (leach ate) flowing from waste dumps and disposal site can cause serious pollution of water supplies.

- Methane (one of the main components of land fill gas) is much more effective than carbon dioxide as a green house gas leading to climate changes.

The primary goal of solid waste management is reducing and eliminating adverse impacts of waste materials on environment and human health to support economic development and superior quality life (Rick, 2017).

2.4 Functional Elements of Municipal Solid Waste Management

In the course of municipal solid waste management there are six functional elements: (i) waste generation; (ii) on-site handling, storage and processing ;(iii) collection; (iv)transfer and transport; (v) processing and recovery; and (vi) disposal (Solomon, 2011).

Functional elements are closely interconnected but they are not necessarily presented in every municipal solid waste management system. In most low and middle income countries, the system is limited to waste generation, handling at the source, collection and disposal at landfills. In most developed countries, every functional element is found within the system(Asi, 2013).

Identification of these functional elements allows description of relationships involved in each element, and development of a framework. As a result, to handle a specific solid waste management it is obligatory to observe the following six elements in combination. These are:

2.4.1 Waste generation

Waste generation encompasses activities in which materials are identified as valueless and either thrown away or gather together for disposal. This functional element is very important because all activities that lead to identification and understanding of solid waste generation rate, volume, composition, area specific variations of waste generation and their expected changes overtime are belong to this component solid waste management. So, this functional element is a vital stage for acquiring accurate information that is necessary to monitor existing management system and to make regulatory, financial and institutional decisions (Gebrie, 2009).

2.4.2 On site handling, storage and processing

This functional element constitutes activities associated with handling, storage, and processing of solid wastes at point of generation. Waste handling involves activities associated with

management of wastes until they are placed in storage containers for collection. It also encompasses movement of loaded containers to point of collection. Storage refers stock up of wastes as soon as they are generated. There are two types of storage activities at source. The first one is temporary storage done at household level as a part of their hygiene. The second type is communal solid waste storage system on public solid waste containers prepared by municipality. While processing at source involves activities such as waste composting and separation of solid wastes for reuse and recycling. All of these components are important for protection of public health and aesthetics and environment (Solomon, 2011).

2.4.3 Collection

Collection involves the process of picking up of wastes from collection points, loading them in to a vehicle, and transporting it to processing facilities, transfer stations or disposal site. In most municipal solid waste management systems, cost of collection accounts a significant portion of total cost. For instance, in industrialized countries collection accounts about 60-70% of total cost, and 70-90% in developing and transition countries (UNEP, 1996). Collection is structurally similar in developing, transition, and industrialized countries, but there are important technical and institutional differences in implementation. In most cases, industrialized countries have more efficiency and effectiveness than developing ones in terms of their approach of collection, role of municipal governments, private-sector participation, and demographic and social factors relevant to collection. In developing countries, collection often involves a face to face transaction between generator and collector. The level of service is low, and generators often have to bring their wastes long distances and place it in containers. As a result many collection activities in developing countries carried out by informal sectors (UNEP, 1996). In general, there are four basic methods of collection described by (Tchobanolous, 1993):

- i. **Community bin**- they are placed in convenient locations where community members carry waste and throw it in. This method is comparatively cheaper than other methods, and most widely adopted method in western countries. For this method to be adopted it is important that bins are covered, aesthetic, attended regularly, kept clean, easy to handle, and separate bins are provided.
- ii. **Curbside collection** - homeowner is responsible for placing containers to be emptied at the curb on collection day and for returning empty containers to their storage location until the next collection.

- iii. **Block collection**- collection vehicles arrive at a particular place or a set day and time to collect waste from households. Households bring their waste containers and empty directly into the vehicle. This method requires a higher homeowner cooperation and scheduled service for homeowner collaboration.
- iv. **Door to door collection**- waste is placed at doorstep at a set time when waste collector arrives. In this method, collector of waste has the responsibility to collect waste separately. This method is very convenient for households, however requires homeowner cooperation.

2.4.4 Transfer and transport

These activities are associated with transfer of wastes from public storage facilities to collection vehicle and the subsequent transport of wastes to disposal site. Transfer refers to movement of waste or materials from primary collection vehicle to a secondary, larger and more efficient transport vehicle. When location of final disposal site is at a long distance from points of collection, transfer stations may be used. With respect to transfer stations, there are two basic modes of operation: direct discharge and storage discharge. In storage discharge refuse is first emptied from collection trucks in to a storage pit or to a large platform. While in direct discharge station, each refuse truck empties directly in to larger transport vehicles (Meenakshi, 2005).

Transportation on the other hand covers all types of vehicles under operation to transport solid waste from its generation point to transfer station and then to treatment or disposal site. All vehicles in operation are considered including manually driven small carts, mechanically driven sophisticated transportation vehicles, and special vehicles for hazardous, bulky, and recyclable wastes. Generally, a properly design transfer and transportation system highly reduces cost of collection (Solomon, 2011).

2.4.5 Processing and Recovery

This functional element includes all techniques, equipment and facilities used both to improve the efficiency of other functional elements and to recover usable materials, conversion products, produce energy, and compost from solid wastes. In addition it also provides several advantages. First, it can serve to reduce total volume and weight of waste material that requires collection and final disposal. Volume reduction also helps to conserve land resources since land is the ultimate sink for most waste materials. On the other side, it also reduces total transportation cost of waste to its final disposal site (Uriarte and Filemon, 2008).

Solid waste processing and recovery has been carried out beginning from separation and processing of wastes at the source. But, separations of mixed wastes usually occur at materials recovery facility, transfer stations, combustion facilities and disposal sites. It often includes separation of bulky items, separation of waste components by size using screens, manual separation of waste components, and separation of ferrous and non-ferrous metals. Then they enter in small and large scale industries for recovery activities. For example, organic fraction of MSW can be transformed by a variety of biological and thermal processes. The most commonly used biological transformation process is aerobic composting and, the most commonly used thermal transformation process is incineration (Solomon, 2011).

2.4.6 Disposal

This is final functional element in solid waste management system. Disposal activities are associated with final dump of solid wastes directly to a landfill site. Today disposal of wastes by land filling or land spreading is the ultimate fate of all solid wastes whether they are residential wastes, or residual materials from materials recovery facilities. However, in most developed countries this method is officially banned allowing only sanitary landfill for final disposal. Because sanitary landfill is not a dump it is an engineered facility used for disposing of solid wastes on land without creating nuisances or hazards to public health and environment (Techobanglous, 2002). Though it is the most common technology around the world, conventional and environmental unfriendly methods such as open-burning, open-dumping, and non-sanitary landfill can still be used as disposal method (UNEP, 2009).

2.5 Transfer Station

Transfer station is one of the elements in solid waste management system. Transfer stations are facilities at which municipal solid waste is dropped off by relatively small vehicles, loaded into larger containers or onto larger vehicles, and hauled to an off-site management facility for further processing or final disposal. It plays an important role in a community's total waste management system, serving as the link between a community's solid waste collection program and a final waste disposal facility. No long-term storage of waste occurs at a transfer station; waste is quickly consolidated and loaded into a larger vehicle and moved off site, usually in a matter of hours.

The primary reason for using a transfer station is to reduce the cost of transporting waste to disposal facilities. Consolidating smaller loads from collection vehicles into larger transfer vehicles reduces hauling costs by enabling collection crews to spend less time traveling to and

from distant disposal sites and more time collecting waste. This also reduces fuel consumption and collection vehicle maintenance costs, plus produces less overall traffic, air emissions, and road wear.

In addition, a transfer station also provides:

- An opportunity to screen waste prior to disposal.
- Flexibility in selecting waste disposal options.
- An opportunity to serve as a convenience center for public use.

Ideally, a transfer station should be sited as close as possible to the centroid of the population served, in order to minimize collection costs, or some distance along the haul route to the landfill. The transfer station should be sited and operated so as to create no environmental or health hazard, and no nuisance.

2.5.1 Transfer technology

The method used to handle waste at the transfer station from the time it is unloaded by collection vehicles until it leaves the site is central to any transfer station's design.

Unloading system

Options for unloading waste from collection or residential vehicles at the transfer station include:

- **Direct Unloading:** It involves collection vehicles discharging directly into transfer vehicles or their loading systems. A two-level arrangement is required, wherein the collection vehicles drive up a ramp to the upper level in order to discharge into a transfer vehicle parked or loading system (i.e., conveyors and/or stationary compactors).
- **Unloading-to-Storage:** It involves collection vehicles discharging into a storage area. From the storage area, wastes are subsequently loaded into transfer vehicles. The storage area may be a platform on the same level as the unloading level, in which case only a two-level arrangement is required. The storage area may be a pit, below the level of the unloading level, and above the level on which the transfer vehicle is parked, in which case a three-level arrangement is required. The storage area is commonly designed to hold the peak quantity of waste generated in one day.

Loading system

There are various systems for loading waste into transfer vehicles. The most common loading systems include:

- **Direct Loading to Transfer Vehicle:** Waste discharged from collection vehicles or from the storage area drops by gravity through a hopper directly into an open-top transfer vehicle
- **Compactor System:** Waste drops through a hopper into a stationary compactor which is mounted on the floor of the lower level of the transfer station. The compactor contains a hydraulically driven ram which pushes the waste from the compactor's receiving chamber into the body of the transfer vehicle. The body of the transfer vehicle must be adequately reinforced to take the force of the ram.
- **Pre-Load Compactor System:** Waste drops through a hopper into a pre-load compactor which is mounted on the floor of the lower level of the transfer station. The pre-load compactor contains a hydraulically driven ram which pushes the waste from the compactor's receiving chamber into a compaction chamber. The compaction chamber is reinforced to take the force of the ram and sized to make a compacted unit which would readily fit within the body of the transfer vehicle. Once the compacted unit of waste is fully formed, it is extruded from the compaction chamber into the transfer vehicle. Because the transfer vehicle does not receive compaction forces, it does not need to be reinforced to take the force of the ram.

The advantages and disadvantages of each method are summarized in the table below.

Table 2-2: Advantage and Disadvantage of Transfer Station Type

Waste Storage Alternatives		
Technology	Advantages	Disadvantages
Direct dump into transfer vehicle	<ul style="list-style-type: none"> - Simple arrangement; little potential for equipment breakdown. - Low capital cost. - Potentially less housekeeping: no tipping floor pit, or compaction equipment to clean and maintain. - Much smaller building size 	<ul style="list-style-type: none"> - Transfer station cannot accept waste unless a trailer is positioned to receive waste. - No short-term storage to accommodate peak inflow periods. - Limited ability to screen and remove unacceptable wastes. - No opportunity for waste diversion or materials recovery.
Tipping floor waste storage	<ul style="list-style-type: none"> - Simple arrangement; little potential for equipment breakdown. - Generally less expensive and provides more operational flexibility - Storage provides “disconnect” between waste receipts and waste loading. (Shortage of empty trailers does not shut down facility.) - Allows for easy screening and removal of unacceptable wastes. 	<ul style="list-style-type: none"> - Garbage on tipping floor can be messy - Requires roll-out space for trucks to pull forward when discharging their loads. - Requires additional fire control equipment (e.g., fire hoses, water cannon) to control fires in waste piles on tipping floor
Transfer Container and Vehicle Loading Alternatives		
Direct Loading to Transfer	<ul style="list-style-type: none"> - Simple - Suitable for a wide range of waste types, including construction debris and bulky 	<ul style="list-style-type: none"> - Odors and litter can escape, and precipitation can make the load heavier.

Vehicle	materials.	
Compaction into trailer	<ul style="list-style-type: none"> - A trailer or container can be completely closed to prevent rainwater entry and odor and liquid from escaping. - Compaction usually achieves high densities 	<ul style="list-style-type: none"> - A heavy trailer or container decreases effective payload (Trailer must be structurally reinforced to withstand the pressure of the compactor). - Capital cost of trailer fleet is greater. - Hydraulic power equipment for compactor can be noisy.
Preload compaction	<ul style="list-style-type: none"> - Allows use of lightweight trailer or container to increase effective payload. - Trailer or container can be completely closed to prevent rainwater entry and odor and liquid from escaping. 	<ul style="list-style-type: none"> - High capital costs - Relatively complex equipment; when it breaks down, can shut down transfer station after short-term storage capacity is full - Totally dependent on availability of electrical power. - A heavy electrical power consumption system - Hydraulic power equipment for compactor can be noisy.

2.5.2 Capacity

A transfer station should have enough capacity to manage and handle the wastes at the facility throughout its operating life. While selecting the design capacity of a transfer station, we must, therefore, consider trade-offs between the capital costs associated with the station and equipment and the operational costs. Designers should also plan adequate space for waste storage and, if necessary, waste processing. The collection vehicle unloading area is usually the waste storage area and sometimes a waste sorting area. When planning the unloading area, designers should allow adequate space for vehicle and equipment maneuvering. To minimize the space required, the facility should be designed such that the collection vehicle backs into the unloading position. Adequate space should also be available for offices, employee facilities, and other facility related activities (EPA, 1995). Factors that should be considered in determining the appropriate capacity of a transfer facility include:

- Capacity of collection vehicles using the facility;
- Desired number of days of storage space on tipping floor;
- Time required to unload collection vehicles;
- Number of vehicles that will use the station and their expected days and hours of arrival;
- Waste sorting or processing to be accomplished at the facility;
- Transfer trailer capacity;

- Hours of station operation;
- Availability of transfer trailers waiting for loading;
- Time required, if necessary, to attach and disconnect trailers from tractors or compactors.

2.5.3 Environmental issues

Developing transfer stations that minimize environmental impacts involves careful planning, designing, and operation. This section focuses on neighborhood quality or public nuisance issues and offers “good neighbor practices” to improve the public’s perception of the transfer station. Design and operational issues regarding traffic, noise, odors, air emissions, water quality, vectors, and litter are discussed below. Proper facility siting, design, and operation can address and mitigate these potential impacts on the surrounding natural environment and the community.

Careful attention to these issues begins with the initial planning and siting of a facility and should continue with regular monitoring after operations begin. Transfer station design must account for environmental issues regardless of surrounding land use and zoning. Stations sited in industrial or manufacturing zones are subject to the same environmental concerns and issues as stations located in more populated zones. Minimizing the potentially negative aspects associated with these facilities requires thoughtful design choices. Identifying and addressing these important issues can be a significant part of the overall cost to develop the waste transfer station.

2.6 Studies of Solid Waste Management in Addis Ababa

Different studies have been carried out regarding the topic of solid waste management in Addis Ababa. All these studies have their own scope and objectives.

One of the first and major studies on solid waste management in Addis Ababa was carried out by Norconsult in 1982 and dealt with waste generation using a technical approach to the management of solid waste in the city. Based on this study, it is estimated that 70% of the waste was organic, 15% paper, and 15% plastic and metals. It also states that 0.150 kg per inhabitant per day was generated.

Another study that was made is the Artelia project. The study provides quantitative data on generation rates and composition of residual waste from households. The research developed a

systematic method to collect data and analyze the waste dynamics in the city. In order to establish the composition and quantities of household waste generated, a waste characterization analysis was carried out in five different housing classes. It can be inferred from the results of the household waste analysis that the waste generation per inhabitant increases as income and purchasing power rise. Furthermore, it can be identified that organic wastes correspond to the largest fraction being produced in households. Accordingly, the composition by mass illustrates that organic waste, i.e. biodegradable waste coming from kitchens and gardens primarily and miscellaneous organic waste, is (48.8 % – 64.7 %), followed by the fine fraction (< 10 mm) (12.3 % – 26.6 %). Paper and cardboard, as well as plastics make up between 3 % and 6 % of household wastes, while wood, textiles, inert material, sanitary products, and charcoal contribute between 1 % and 6 % of the composition of the waste depending on the housing class. The estimated average household waste generation per day was 0.190 kg/cap/day (Artelia, 2013).

Yet other review was made on domestic solid waste management and its environmental impact by Ali and Eyasu (2017). This review examined the composition and impacts of domestic solid waste and evaluates the existing waste management practices in the city. The review concludes that the main burden of the city's municipal wastes comes from residential areas, making them the main focus for the waste management strategy. Despite the practice of waste management for almost 60 years, the progress when compared with the degree of urbanization and population pressure is not as expected. The author recommends the city administration should focus on integrated waste management technologies and increasing the capacity of the informal sector participating in waste management (Ali and Eyasu, 2017).

Additionally, Camilla made a study that deals with the informal plastics recovery system in Addis Ababa. The objective of the study was to explore the organization and the actors involved in the system. Furthermore, the study tries to estimate the size of the informal sector, the amount of materials collected, the quality of the materials, and the economic aspect of the activities in order to evaluate the performance of the system. This study has shown that thousands of individuals in Addis Ababa depend on the recovery of plastic materials in order to make a living. Moreover, the activities have been shown to be economically profitable and to play an important role in solid waste management. It is argued that both a lack of a formal system for the recovery of plastic materials and the government's lack of awareness of the informal sector has made it possible for the sector to develop without interference. However, the governmental ignorance of the informal plastics recovery system as well as civil society's

lack of trust and creditability in the government has proven to be one of the main difficulties confronting the plastics recovery system today. This article argues that the government's approach towards recovery activities is centralized, bureaucratic and ignores the potential contribution of the informal sector, with little public participation in the decision process (Camilla, 2005).

Camilla made yet another study that explores the management of solid waste in Addis Ababa. This study tried to understand the underlying reasons for the poor solid waste management situation that the city is faced with today by using governance and urban political ecology as a theoretical framework. It also tried to identify aspects and strategies that should be in place in order to improve solid waste management and to achieve more equitable development among the various actors` involved. The study showed how power and politics affect the way that solid waste is managed in Addis Ababa, and the author argued that the promise of good governance has not resulted in the official goals being attained, but rather a rhetorical use of policies and reforms. The Ethiopian Government has adapted good governance policies to suite its own interests and agendas, and this has not led to improved governance and a more efficient management of solid waste in the city (Camilla, 2013).

A different study made by Yirgalem(2005) presents the impacts of poor landfill management on the local community, by investigating the performance of Repi landfill site and public reaction to its impacts. The study concludes that the growing concerns of health and environmental risks in the landfill area are now becoming more serious as different incompatible land uses are surrounding the site. By any standards of waste disposal systems, it is not acceptable to use the Repi site for disposal purposes. Incompatible land use activities such as settlements and other public assembly areas are located within unacceptable distances from the site. The fact that the site has no appropriate cover means the noxious smells are carried as far as 2 kilometers away by prevailing winds (Yirgalem, 2005).

Another study on solid waste management in Addis Ababa is made by Aklilu regarding appropriate landfill area. In this study, selected sites for an appropriate landfill area in Addis Ababa City are determined by using the integration of Geographic Information Systems (GIS) with Multi-Criteria Evaluation (MCE) and Remote sensing (RS) technology. At the end of the analyses, thirteen (13) selected sites are determined. Among all, the most preferable solid waste landfill site was located in the eastern part at Bole sub-city (Aklilu, 2015).

Chapter 3 BACKGROUND TO THE RESEARCH CONTEXT OF ADDIS ABABA

3.1 Overview of Addis Ababa

Addis Ababa is home to 25% of the urban population in Ethiopia and is one of the fastest growing cities in Africa. It is estimated that today Addis Ababa has 3.7 million inhabitants and is still growing rapidly (3.69% per year) due to immigration from rural areas and its own natural increase. The city core has high density (around 15,000-30,000 people per km), concentrating around 30% of the population on 8% of the land in Addis Ababa (World Bank, 2015).

The city has shown extensive physical growth over the years. In 1920s, the area covered by the city was estimated to be 33 km², by 1984 it had grown to 224 km² and by 2003 it was estimated to be 527 km² (CSA, 2009). Now, the city covers built - up land area of 647 Km² (World Bank, 2015).

Addis Ababa is mainly an administrative, commercial and service city. Due to Addis Ababa's function as the capital city, the seat of the Ethiopian Government, the African Union and various international organizations and embassies, over the years the city has been given the majority of social and economic infrastructure. Despite construction activities in recent years to provide housing, commercial buildings and new roads, the urban services and infrastructure cannot cope with the city's rate of development (Camilla, 2013).

The physical growth and development of the city have been affected by the lack of efficient urban management. Since the Italian occupation in the period 1936–1941, six master plans have been prepared for Addis Ababa, but none has been implemented and this has resulted in spontaneous urban growth and development in the city (Yirgalem, 2008).

3.2 Organization of Addis Ababa Administration

Addis Ababa was comprised of six major administrative zones that were further divided into 28 political regions called Weredas. These in turn were further divided into 345 administrative (and political) entities called Kebeles. However, since the year 2000, administrative changes have resulted in the creation of new administrative areas (UN - HABITAT, 2003).

The new administrative structure of Addis Ababa is based on the creation of 10 sub-cities, which were further divided into 102 weredas (the smallest administrative unit).

3.3 Organization of the Solid Waste Management

This section describes how solid waste management has been organized and the reasons behind the reorganizations of the Solid Waste Authority.

The way that solid waste has been managed and the service provided in Addis Ababa have changed during the last 18 years. After Federal Democratic Republic of Ethiopia(FDRE) came to power, the first organization that took responsibility for waste management was the City Health Bureau under the department of Environmental Health Care.

From 1994 to 2003, solid waste management was organized under the City Health Bureau in the Department of Environmental Health Care. In this organization, solid waste management was overshadowed by many other activities carried out by the bureau. The long bureaucratic chain also made it difficult to coordinate the different actors and hindered efficient mobilization and use of resources (SBPDA, 2003, 2004b).

As part of the national decentralization process in 2003, responsibility for solid waste management was reorganized so that it came under the Sanitation, Beautification and Park Development Authority (SBPDA). As part of the reform, departments responsible for solid waste disposal were also established at Sub-City and kebele levels with the aim of decentralizing the services and increasing their efficiency. The responsibility of SBPDA was to act as a regulatory and policymaking body to set standards, coordinate activities among sub-cities, deal with cross-cutting issues, deliver technical support and capacity building, manage the city's dump site, run public awareness program, and conduct research. The sub-cities were responsible for the daily operation of activities within solid waste, such as collection and transport. In addition, they were responsible for conducting campaigns and undertaking activities related to composting and recycling. Each Sub-City had its own budget and was responsible for ensuring long-term management of solid waste, and implementing program and regulations, as well as monitoring and evaluating them. The kebeles were responsible for the daily operation of solid waste management in their neighborhoods, control, and reporting to the sub-cities the services provided.

In 2009, the SBPDA was reorganized in line with business process re-engineering (BPR). The agency changed its name to the Solid Waste Management Agency and Landfill Project Office.

Compared with the previous organization of the agency, the structures were more or less the same. The main change was that the Park and Cemetery Department was taken out and established as an independent agency. Further, the reorganization aimed at giving even more power to the sub-cities and the kebeles.

A comparison of the structural changes of the agency in the three different periods reveals that the city administration has decentralized responsibility for solid waste down to Sub-City and kebele levels. The Solid Waste Management Agency has also become more specialized; it focuses only on solid waste, is not seen as part of the Health Bureau, and does not have responsibility for areas such as park and beautification. Currently, the various tasks within solid waste are organized under different departments, such as the Planning Department and the Implementation and Operation Department, which reflects how solid waste management has gained more attention in recent years. However, more than structural changes are needed to improve the management

3.4 Regulations Governing Solid Waste

Today, there are several laws and regulations concerning the management of solid waste in Addis Ababa. At the national level, the Environmental Protection Authority (EPA) has the main responsibility for implementing laws to protect the urban environment and the management of solid waste (Camilla, 2013).

The first proclamation regarding specifically to solid waste was passed in 2007. The aim of the policy was to enhance at all levels capacities to prevent the possible adverse impacts while creating economically and socially beneficial assets out of solid waste (FDRE, 2007: 3525). The proclamation may be cited as Solid Waste Management Proclamation No.513/2007. The Proclamation has five parts. The first part of the proclamation defines the terms in use and declares the title and objective. Part two refers to the obligations of urban administrations to ensure the proper planning, implementation, and monitoring of solid waste. The focus is on city administrations' responsibilities and on decentralizing responsibilities to the lowest levels of administration in order to fulfill the obligations. In the third part, the proclamation focuses on regulations to manage waste glass, plastic bags, used tires, food, household waste, and construction waste in a sustainable manner and with focus on proper handling, segregation, reuse, and recycling. Part four deals with transportation and disposal of solid waste, where the focus is on technical inspection of vehicles used for transporting solid waste

as well as ensuring proper management of disposal sites in line with the environmental regulations. The last part of the proclamation declares penalties when these guidelines are trespassed.

There are two other proclamations relating to waste management and to environmental policy. The proclamations are 'Environmental Impact Assessment Proclamation No.299/2002' and 'Environmental Pollution Control Proclamation No.300/2002'. The content of these proclamations is such that it sets the responsibilities of the authorities and actors concerned in the matter and declared penalties when the bodies fail to meet their responsibilities. The Environmental Policy of Ethiopia consists of general attitudes to protect and preserve all natural resources in the country.

3.5 The Solid Waste Management Situation in Addis Ababa

The solid waste situation in Addis Ababa is characterized by increasing waste generation due to increased levels of consumption, growing immigration from the rural areas, and the city's own demography. Waste accumulates in the urban environment, causing bad odors and clogging the drainage channels, and accumulations of waste have become breeding grounds for insects and vermin which pose a threat to human health and the urban environment (SBPDA, 2003).

3.5.1 Waste generation and composition

Addis Ababa City Administration operates with data on waste generation and composition that were compiled by Norconsult in 1982. Given that the data are 30 years old, they are no longer representative for the current situation. The Sanitation, Beautification and Park Development Authority (SBPDA) estimate that currently the generation of waste per capita per day is 0.221 kg. Based on the study conducted by Norconsult in 1982, it is estimated that 70% of the waste was organic, 15% paper, and 15% plastic and metals. However, these data are highly questionable, and do not give a representative picture of the waste generation and composition in the city. Addis Ababa has grown rapidly in recent years, and its population and physical size have more than doubled since the study was conducted in 1982. Moreover, the consumption habits have changed as a result of the growing middle-class. New products have entered the market, and especially plastic and electrical items have increased compared to 30 years ago, in the early 1980s. Enormous construction activities have also taken place in the city in the last 10 years (i.e. Since the early 2000s) and it can be assumed that the amount of construction waste has increased dramatically compared to when Norconsult's study was

conducted. In addition, most of the inorganic materials are reused and then sold or given away for further reuse or recycling by the informal recycling sector operating in the city, and are not even entering the municipal waste stream (Camilla, 2005).

According to the SBPDA, 71% of waste is generated by households, 10% is disposed of in the streets, and 9 % is generated by commercial institutions, 6% by industries, 3% by hotels, and 1% by hospitals. The estimation was made based on the research conducted in 1982.

3.5.2 Solid waste services provided to households

Between 1994 and 2003 there were mainly two types of collection system offered by the city administration. One system was a door-to-door service offered to households located close to the main roads. Shortages of vehicles and frequent breakdowns made it difficult to keep to schedules, resulting in a poor and inefficient collection system with irregular and few collection times. In addition to the door-to-door service, waste was also collected via municipal containers placed near the main roads. Hence, many of the households' members had to walk long distances in order to dispose their waste in the containers. Due to lack of containers and collection trucks and frequent breakdowns of the trucks, it was common to see containers overflowing with waste. As a consequence, people commonly resorted to either burning or disposing of their waste in nearby rivers or on open plots of land (Camilla, 2005; Zelalem, 2006). During this period the informal sector saw the opportunity to start offering to households a waste collection service either once or twice a week for a monthly fee of 10–15 birr.

In 2003, the informal pre-collectors operating in the city were formalized. The formalization was part of micro- and small-scale enterprise (MSSE) development in the city and in line with SDPRP supported by international donors to privatize and improve urban services and create employment among the urban poor (SBPDA, 2004a). In addition to the pre-collectors, the container system continued to be offered to those living along the main roads. However, the containers were placed within neighborhoods and controlled by officials from the kebeles, in order to ensure that the MSSEs disposed of the waste in a proper manner. In this period (2003-2005) the solid waste situation improved, but the services provided were offered only to those who could pay for them, thus leading to segregation in service provision among the citizens. In addition to the container system and the door-to-door collection by MSSEs, the city administration also employed 1137 street sweepers in 2003 (SBPDA, 2004a). However, the street sweepers only cleaned the main roads and avenues, leaving most of the city without access to the service. In 2009, the MSSEs were

reorganized into cooperatives in line with BPR. The cooperatives were employed by the kebeles and were paid according to the amount of waste collected per cubic meters. The reorganization was intended to improve service, increase employment levels, and collect waste fees through the water bill system. The introduction of the new system meant that everybody had to pay and everybody should get the service. According to the Solid Waste Management Agency, the implementation of the new system was successful: it had improved the amount of waste collected in the city and contributed to the employment of almost 13,000 waste collectors.

3.5.3 Storage and transportation of solid waste

From 1994 to 2003, the city administration had the main responsibility for the transportation of solid waste. Over the years there have not been enough containers for waste collection in Addis Ababa and the condition of many of the containers is poor. In 2003, the municipality had 512 (8 m³) containers, which meant that one container served 7500 households. By 2007, the number had increased to 587, but this did not make any significant difference in terms of improving the collection capacity (SBPDA, 2003).

However, in 2009, in line with BPR, the responsibility for maintaining and running the trucks was given to the sub-cities in an attempt to improve the efficiency of the transportation of waste. Further, the agency bought 44 new trucks in 2010, and implemented three shifts in 2010 (Camilla, 2012).

3.5.4 The Repi dump site

The current dump site at Repi covers an area of 25 ha and is located in the south-western part of Addis Ababa, in Kolfe Keraniyo Sub-City, 13 km from the city centre. Repi is the only dump in Addis Ababa and when the site was established in 1964 it was located on the outskirts of the city. With the growth and expansion of the city, the site has become surrounded by settlements and currently it represents a threat to human health and the environment.

Today, the dump is full and is improperly managed. There is no drainage to capture leakages or runoff. Further, the dump is not enclosed by a fence and is not covered with soil on a daily base. Due to lack of a weighbridge, the amount of waste disposed on the site during the years has been poorly recorded (Yirgalem, 2001). In 2003, there were four bulldozers, but only one was working (SBPDA, 2003). Further, the road leading to the site is in a very poor condition and becomes almost unusable during heavy rains. Hence, on some days no waste can be collected

from the city. Currently, the dump is also a work site for 500 scavengers, who make their livelihood by collecting waste both for their own consumption and for resale (Camilla, 2013).

3.5.5 The informal recycling sector in Addis Ababa

The key role in the informal waste recycling process is played by a market place named Minalesh Tera. Minalesh Tera is located in Merkato in Addis Ababa; one of the biggest open markets in Africa. Minalesh Tera is the block where all the useful waste comes to be sold and recycled again.

The informal recycling system in Addis consists of different actors who are involved in activities related to the collection, trade, reuse, and recycling of waste. The system consists of households, foragers, scavengers, Qorqoroalleh, pre-collectors, wholesalers, middlemen, small-scale craftsmen, and local industries.

At the bottom of the hierarchy there are the scavengers who collect waste materials from the municipal landfill. It is estimated that today there are 500–600 on-site scavengers who make a living from collecting waste materials for their own consumption or for reuse or recycling. Most of the scavengers are individuals who live in the village nearby. The materials collected for reuse and recycling are stored either at the site or in the village nearby. The most common practice is to store the materials until there is a large enough amount to sell to middlemen or to rent a truck and transport the waste to Minalesh Tera.

At the next level, one finds the Qorqoroalleh, who buy materials mainly from households and to a limited extent from the foragers, pre-collectors. The Qorqoroalleh differ from the foragers and the scavengers because they buy materials before they enter the waste stream. The quality of the materials they collect is therefore higher than that collected by foragers and scavengers. Moreover, the Qorqoroalleh have a strong upward link in the system to the wholesalers who operate in Minalesh Tera.

Waste materials collected in other cities are transported to MinaleshTera, and traders from rural areas travel to MinaleshTera to buy materials wholesale for further sale in rural areas. Ranked above the wholesalers are the small-scale craftsmen, who are mainly located in MinaleshTera and make use of waste materials to produce local items such as electrical stoves, large metal plates used to wash clothes, shoes, and cooking equipment, and to repair broken items such as luggage, old toys, and old shoes. In addition, there are rural traders and industries who buy waste for recycling (Camilia, 2013).

Chapter 4 METHODOLOGY

4.1 Description of the study area

Addis Ababa is the capital city of Ethiopia. The city is geographically located between $8^{\circ} 55'$ and $9^{\circ} 05'$ N Latitude and $38^{\circ} 40'$ and $38^{\circ} 50'$ E Longitude with an average altitude of 2500 above mean sea level. The city is divided into 10 sub-cities, which were further divided into 102 woredas. The city covers built - up land area of 647 Km². Currently more than 3.6 million people resides and it is a big and sprawling city.

4.2 Method of Data Collection

The main data collection methods used in the study was semi-structured interviews and field survey. Moreover, relevant documents were reviewed in order to collect background information on the solid waste management situation in Addis Ababa.

4.2.1 Semi – structured interviews

Semi-structured interview was the main method that was used in the study. The interviews were targeted for stakeholders and decision-makers in the field of solid waste management. The stakeholders were chosen based on their respective role within the solid waste management system. Semi-structured interview was chosen because it is open to other information and aspects that could come up during the interviews that was not thought about or been aware of in advance.

Regarding primary waste collection, data was collected from representatives of the following institutions and concerned bodies.

- Cleansing Management Agency (CMA): The CMA is responsible for the waste management in the city. The CMA on city, sub-city and woreda level was interviewed.
- Pre collector groups: They are responsible for the collection of waste from households in their respective woredas. This is done by door- to-door collection.

For secondary waste collection, data was collected from:

- Cleansing Management Agency (CMA): The CMA on city and sub-city level was interviewed.
- Truck drivers and assistants: they are in charge of the operation of the trucks that transport the waste to the final dump site.

4.2.2 Field survey

Solid waste management is one of the most visible urban services and thus observation can provide much information about what is going on in the city. Observation is essential to gain an understanding of the practices of solid waste management and to compare the personal observations with the narratives of the various participants .

For primary waste collection, pre collector groups were monitored and their activities were tracked in a field survey. Data was recorded on matters such as duration of time for different activities of the pre collectors, how they operate, and volume of waste collected.

For secondary waste collection, the operating trucks were monitored to collect detailed information on the way of operation, the volume of waste collected by different truck types, time used up during activities and other relevant data.

4.2.3 Document Review

Data available in municipal documents and reports were reviewed. The secondary data obtained was used to enhance the understanding of the problem and for triangulation and verification of the primary data collected.

4.3 Sample size

The sample size was calculated by using online sample size calculator. There are a total of 735 pre collector groups in the city. Accordingly, the sample size for primary waste collection data survey was determined to be 250 by using 95% confidence level of ± 5 .

For secondary collection data survey, two samples from each truck type available in the sub city were selected for monitoring.

4.4 Data Processing

The collected data was processed to determine the productivity of the primary and secondary collection.

4.4.1 Primary Collection

Productivity of primary collection is defined as volume of waste collected per day divided by the number of workers:

$$P_{\text{collection}} = \frac{V_{\text{waste}}}{N_{\text{worker}}} \dots\dots\dots \text{Equation 4.1}$$

Where: $P_{\text{collection}}$ = Collection productivity ($\text{m}^3/\text{day}/\text{worker}$)

V_{waste} = Volume of waste per day (m^3/day)

N_{worker} = no of workers

The total collected volume was calculated as:

$$V_{\text{pu}} = W * H * L \dots\dots\dots\text{Equation 4.2}$$

Where: V_{pu} = Volume of push cart (m^3)

W = Width (m)

H = Height (m)

L = Length (m)

Collected volume of a tour:

$$V_{\text{tour}} = V_{\text{pu}} * \text{Pu}_{\text{level}} \dots\dots\dots\text{Equation 4.3}$$

Where: V_{tour} = Collected Volume of a tour (m^3)

V_{pu} = Volume of push cart (m^3)

Pu_{level} = Pushcart filling level

Total collected volume is:

$$V_{\text{T}} = \sum V_{\text{tour}} \dots\dots\dots\text{Equation 4.4}$$

Where: V_{T} = Total collected volume (m^3)

V_{tour} = Collected Volume of a tour (m^3)

The total collected volume can also be calculated as:

$$V_{\text{T}} = N_{\text{bags}} * V_{\text{avg}} \dots\dots\dots\text{Equation 4.5}$$

Where: V_{T} = Total collected volume (m^3)

N_{bags} = Number of collected bags

V_{avg} = Average volume of a bag (m^3)

Average number of pushcart workers:

$$\text{Pu worker}_{\text{avg}} = \frac{\sum(N_{\text{pu worker}} * t)}{T_t} \dots\dots\dots\text{Equation 4.6}$$

Where: $\text{Pu worker}_{\text{avg}}$ = Average number of pushcart workers

$N_{\text{pu worker}}$ = Number of pushcart workers

t = Working time (min)

T_t = Total working time of pushcart workers (min)

Average number of collectors:

$$\text{Collector}_{\text{avg}} = \frac{\sum(N_{\text{collector}} * t)}{T_t} \dots\dots\dots \text{Equation 4.7}$$

Where: Collector_{avg} = Average number of collectors

$N_{\text{collector}}$ = Number of collectors

t = Working time (min)

T_t = Total working time of collectors (min)

Average productivity of the whole group per day is calculated as:

$$P_{\text{avg}} = \left(P_{\text{collectors}} * \frac{\sum(N_{\text{collector}} * t)}{\sum(N_{\text{collector}} * t) + \sum(N_{\text{pu worker}} * t)} \right) + \left(P_{\text{pu}} * \frac{\sum(N_{\text{pu worker}} * t)}{\sum(N_{\text{collector}} * t) + \sum(N_{\text{pu worker}} * t)} \right)$$

.....Equation 4.8

Where: P_{avg} = Average productivity of the whole group (m³/worker/day)

$P_{\text{collectors}}$ = Average productivity of collectors (m³/worker/day)

P_{pu} = Average productivity of pushcart workers (m³/worker/day)

N_c = Number of collectors

N_{pu} = Number of pushcart workers

t = Working time (min)

The daily primary collection capacity (m³/day) is equal to

$$P_{\text{avg}} * N_{\text{worker}} * N_{\text{group}} \dots\dots\dots \text{Equation 4.9}$$

Where: P_{avg} = Average productivity of the whole group (m³/worker/day)

N_{worker} = Average number of workers per group

N_{group} = Number of groups in the city

4.4.2 Secondary waste collection

Productivity of secondary waste collection is defined as the total volume of waste per hour picked up at container sites and dumped at the dumpsite during the duration of one shift.

Collection productivity (m^3/hr) is calculated as:

$$P_{truck} = \frac{V_{waste}}{t_{avg}} \dots\dots\dots \text{Equation 4.10}$$

Where: P_{truck} = Truck productivity (m^3/hr)

V_{waste} = Volume of waste per day (m^3/day)

t_{avg} = Average working time (hour)

Daily secondary collection capacity (m^3/d) is:

$$N_{trucks} * t_{avg} * P_{truck} \dots\dots\dots \text{Equation 4.11}$$

Where: N_{trucks} = Number of trucks

P_{truck} = Truck productivity (m^3/hr)

t_{avg} = Average working time (hour)

4.4.3 Transfer station design

Step 1: Identify the service area

Step 2: Select a design period

Step 3: Estimate the amount of waste generated within the service area including projected changes such as population growth and waste volume.

Step 4: Estimate the total demand for the design year

Step 5: Collect the necessary data: The types of vehicles delivering waste, types of materials to be transferred, the availability of transfer trailers and how fast these can be loaded.

Step 6: Plan the facility size to accommodate waste deliveries

Chapter 5 RESULTS AND DISCUSSION

5.1 Primary Waste Collection

5.1.1 General characterization of primary collection

The following section gives general information about primary collection in woredas. It is based on the questions asked at the CMA of the chosen woredas and the leaders of the sampled pre collector groups.

The CMA stated that in average there are seven pre collector groups and 52 pre collectors working in one woreda. There is an average of 10 workers per group. In the majority (70 %) of the monitored woredas, the number of households per pre collector group is between 500 and 1250. The criteria that were used for the division of collection area are administrative borders (55%), no of Households (30 %) and man power of the group (15%). The decision on how many members work in one pre collector group is made by the respective woreda.

The equipment the pre collectors' work is 65% pushcart and 35% collection truck. The collected waste is brought to communal containers or skipping point, until the pre collectors transfer them into compactor truck. 36% of the groups stated that they work with containers, while the remaining 64% work with garbage collection compactor trucks. The container collection frequency is on average four times a week.

Concerning working days of the monitored pre collector groups, in average they work six days a week. The frequency of the groups serving an area is on average once a week.

5.1.2 Collection methods of pre collectors

To characterize the different working methods used by the pre collectors, the general methodology of the primary collection needs to be exemplified first. The pre collectors serve areas in a door-door collection. Then, the collected waste is transported to a garbage container or a skipping point, where it stays until the pre collectors transfer them into compactor truck.

The pre collectors' collection methods can be divided into three categories based on the equipment used by the groups. These are pushcart method, pushcart - collector method and collection truck method. The pushcart method is in which all members work directly with the

pushcart. In this mode of collection, the pre collector group own a pushcart and all workers stay more or less near to it.



Figure 5-1: Pushcart method of collection

The pushcart - collector method, as the name indicates, is in which part of the group work with the pushcart while the rest of the group work as collectors. Accordingly, some of the workers walk through the streets knock on doors and take the waste from the households and store it temporarily at places good to be reached with a pushcart (Figure 5-2). The group with the pushcart moves from one temporary storage to another point and loads the waste to the pushcart to discharge it at a municipal container or transfer station.



Figure 5-2: Temporarily stored waste

In the collection truck method waste is set out by the residents at the front street (curb side). Then, the pre collectors collect the waste by using small volume vehicles.



Figure 5-3: collection truck

The distribution of the three collection methods for the surveyed groups is displayed in Figure 5-4.

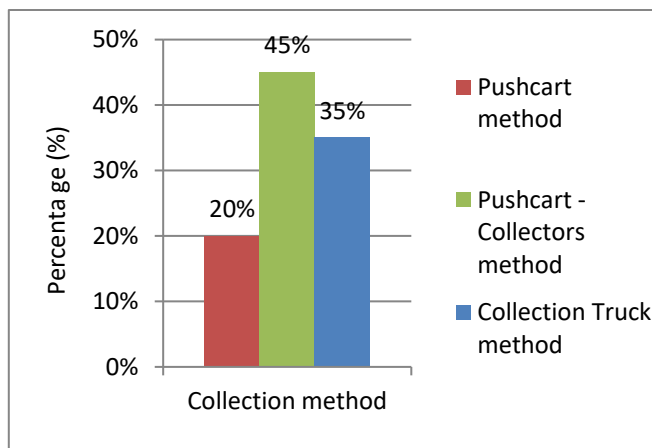


Figure 5-4: Distribution of collecting methods for the monitored pre collector groups

5.1.3 Transfer at the skipping point

The pre collectors collect the waste from households and transport it to the municipal garbage containers or skipping points. The groups work either with a municipal garbage container or the waste is collected directly with a compaction truck from the skipping point. If the groups work with a container, they empty the bags in which they transported the waste, into the container. If the waste was collected with a compaction truck, the waste was stored in bags at the skipping points until the truck arrived and then the bags were emptied by the pre collectors into the truck. The pre collectors had to wait for the truck until it arrived which extended their working day additionally. The containers are of size eight cubic while the compactors have a capacity of 40 or 80 cubic meter.



Figure 5-5: Transfer at the skipping point



Figure 5-6: Transfer at the container site

5.1.4 Productivity determination

The productivity of the pre collector groups was determined using Equation 4.1. The productivity was determined separately for the different working methods. The steps followed for the different working methods are described below.

5.1.4.1 Average productivity of pushcart workers

For the pushcart collection method, the pushcart volume is calculated first by using Equation 4.2.

Next, the volume of waste collected in the respective tour is calculated using Equation 4.3.

The average productivity of pushcart workers is the total collected volume of waste in a day divided by average number of pushcart workers. The total collected volume is calculated using Equation 4.4. The average number of push cart workers is calculated using Equation 4.6.

The average productivity of pushcart workers is then determined using Equation 4.1.

5.1.4.2 Average productivity of collector's

Since these groups did not work with pushcarts, it was not possible to measure the volume of the collected waste directly. Therefore, for these groups the volume of the collected waste is calculated using Equation 4.5.

Determination of the average volume of a bag was done at five of the monitored groups to get representatively value, because it was not possible to count the number of bags at every monitored group, as this would have taken time and interrupt the pre collectors' work. Table 5-1 shows the volume per bag.

Table 5-1: Volume per bag

	Volume (m ³)	No of bags	Volume per bag (m ³)
	9.8	139	0.07
	6.8	127	0.05
	3.9	65	0.06
	7.4	131	0.056
	5.2	111	0.04
Total	33.1	573	

$$\begin{aligned} \text{Average volume of a bag (m}^3\text{)} &= \text{Total Weight [kg]} / \text{Total no of bags} \\ &= 33.1/573 = 0.058 \end{aligned}$$

$$\text{Total collected volume (m}^3\text{)} = \text{Number of collected bags} * 0.058$$

The average collectors' productivity per day is the total collected volume of waste per day divided by the average number of collectors. The average number of push cart workers is calculated using Equation 4.7. The average productivity of collectors is then determined using Equation 4.1.

5.1.4.3 Average productivity of pushcart - collector method

The productivity of this method is calculated by the weighed sum of pushcart and collectors productivity (Equation 4.8).

The results of the productivity of each of the sampled groups are listed in Annex VII.

On average, the collection productivity is determined to be 2.12 m³/ worker/day for the pushcart method and 2.81m³/worker/day for the Pushcart - Collectors method.

5.1.4.4 Average productivity of collection truck

For the collection trucks, the productivity is defined as the total volume of waste collected and dumped at the skipping point during the working hour. Truck productivity is calculated by dividing the average amount of waste collected during one day with the average working hour.

During the field survey all the activities performed by the pre collectors were observed. The collection trucks have carrying capacity of 4.5 m³ volumes of waste and the pre collector groups complete, on average, seven (7) tours in a day. This makes the total volume of waste collected in a day 31.5m³/day. The average working hour in a day is determined to be 7.5 hour. The longest time was spent on streets, driving to or from households to the skipping points. Accordingly, the average productivity of the collection trucks was determined to be 4.2m³/hr.

5.1.5 Primary collection capacity

The daily collection capacity of primary collection that existed at the time of this study is estimated by taking into account the number of pre collector groups in the city. It was calculated by using Equation 3.9.

The average productivity of the different working methods and the no of worker per group were directly taken from the data received during the tracking of the pre collectors. Data from interview at the Cleansing Management Agency (CMA) of the city was used on the number of pre collector groups in Addis Ababa. There are 735 pre collector groups in the city. The result from the calculation is summarized in Table 5-2.

Table 5-2: Primary collection capacity

Collection capacity of pushcart methods						
Collection method	% age distribution of collection method	no of groups	Average group size	Productivity (m ³ /worker* day)	Days per week	Annual collection capacity (m ³ /a)
Pushcart method	20%	147	4	2.12	5	299174.4
Pushcart - collectors method	45%	331	6	2.81	5	1339358.4
Collection capacity of the truck method						
Truck type	% age distribution of collection method	No of truck	Working hour per day (hr)	Productivity (m ³ /hr)	Days per week	Annual collection capacity (m ³ /a)
Collection truck	35%	257	7.5	4.2	4	1554336

Total	3192868.8
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5.1.6 Factors affecting the primary collection productivity

5.1.6.1 Collection method

As explained previously, there were two different working methods distinguished. One of the main influencing factors is the choice of the collection method because the two methods had different average productivities as shown in Table 5-3.

The groups working with the pushcart - collectors' method had the highest average productivity per day. The pushcart method had the second highest productivity per day. The productivity difference between the pushcart - collectors method and the pushcart method may be explained with lesser workload of the pushcart in the pushcart - collectors method. The pushcart is just stopped to load at the temporary waste storage point and to unload it at the skipping point. Also, the pre collectors working as collectors also have lesser workload, because they do not have to wait for the pushcart and thus work without discontinuities.

5.1.6.2 Weather

There were no measureable influences detected from the weather on the productivity. However, effects from the weather were observed during field survey. When it rained, many of the groups abandoned their work for that day. In addition, the groups stopped working when it got very hot, because the solid waste starts to emanate very bad odor when hit by the sun. Therefore, the groups often started work early in the morning and stop their work before noon.

5.1.6.3 Equipment

Another impact on the productivity was the state and size of the pushcarts. Regarding the state of the pushcarts, variations between new pushcarts that were in excellent condition and old ones with some parts broken were observed in the field. Also, there was a variation in the dimensions of the pushcarts, which had impacts on the productivity as well. During the field survey it was observed that both small sized pushcart and a very big ones do not contribute to a high productivity. This was because when the pushcart was too big the cart was too heavy and difficult to handle and it took the groups a lot of energy to push it further. In addition, they had complications to unload the cart because it was too high to reach the bags at the bottom. On the other hand, a cart too small can't be loaded effectively and the group had to cover additional trips to the container and back.

5.1.6.4 Interaction with Households

The interaction of the pre collectors with the residents also has an impact on productivity. This is because the collection speed of the pre collectors depends on the time it takes for the residents to bring the waste. When the pre collectors work early in the morning when residents were sleeping, it took longer time till the waste is brought outside. It is also preferable if the waste is stored next to the gate so that that it takes less time than when it has to be collected behind the house.

5.1.6.5 Motivation

The impact of the pre collectors' motivation and attitude to work needs to be mentioned. The motivation of a group cannot be measured in the field; however, it was recognizable. There was a great difference in productivity when the workers were motivated to walk fast and collect much waste, and when they work slowly because they were not enthusiastic. It was observed that the groups were highly motivated with money. They serve households who paid them additional money more frequently and more devotedly than others.

5.2 Secondary waste collection

5.2.1 General characterization of secondary waste collection in Addis Ababa

5.2.1.1 Organizational structure

In each sub city, there is a waste management office. The offices are responsible for the secondary collection of waste from different sources. The sub city waste management offices own the collection trucks and are also responsible for maintenance and refueling.

The schedules according to which waste is collected by the trucks are designed at sub city level. The sub city offices decide on the appropriate number of drivers and assistants. They can also request for new trucks to the CMA. Because of this structure, each sub city follows a slightly different way of managing the secondary collection of municipal solid waste.

5.2.1.2 Equipment

In Addis Ababa, two different types of trucks were used to deliver waste from the container sites to the dumpsite: container truck and compactors. A container truck is able to pick up the whole container and transport 8 m³ of waste. A compactor needs to be loaded with waste manually and has a capacity of 40 m³ and 80m³.



Figure 5-7: Container truck



Figure 5-8: Compactor truck

In total, 140 waste trucks are available for secondary waste collection in the sub cities of Addis Ababa. Out of these, only 97 trucks were functional at the time of the study. Figure 5-9 shows the distribution of the number of trucks in operation.

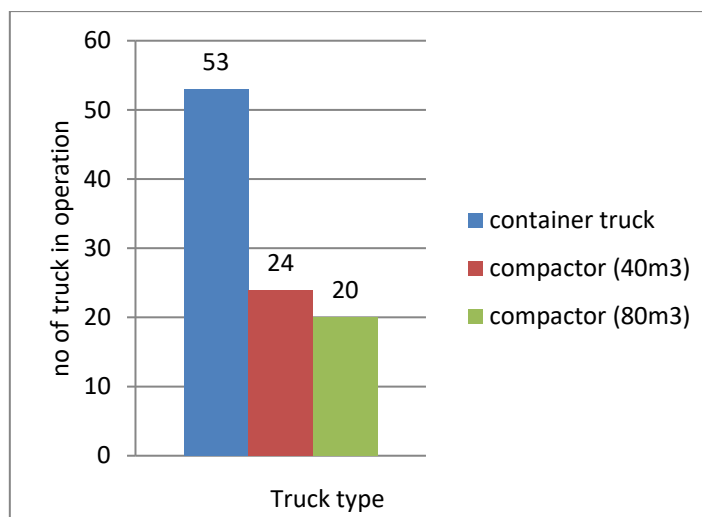


Figure 5-9: Number of trucks in operation

The distribution of the trucks among the sub cities is shown in Table 5-5.

Table 5-3: Operating trucks per sub city

	Number of trucks in operation			Number of trucks in repair		
	Compactor (80m ³)	Compactor (40m ³)	Container (8m ³)	Compactor (80m ³)	Compactor (40m ³)	Container (8m ³)
AkakiKaliti	0	3	8	-	-	5
Nefass Silk Lafto	1	3	11	-	-	12
KolfeKeraniyo	2	4	5	-	-	3
Gulele	2	3	3	-	-	2
Lideta	2	1	0	1	-	0
Kirkos	4	1	1	-	-	0
Arada	4	1	3	-	-	1
Addis Ketema	2	3	7	-	-	3
Yeka	1	2	5	-	-	2
Bole	2	3	10	-	-	13
Total	20	24	53			41

5.2.1.3 Work shift

The sub cities decide the number of tours (i.e. from a skipping point to the dump site) that has to be covered in 24 hours. It is up to the drivers to arrange the working time.

5.2.2 Determination of trucks productivity

5.2.2.1 General performance during the 24hr shift

Container trucks carry less volume of waste and thus had to visit the dumpsite more often and complete more tours than compactors. Consequently, they drove longer distance than compactors and carried the least amount of waste (Figure5-10).

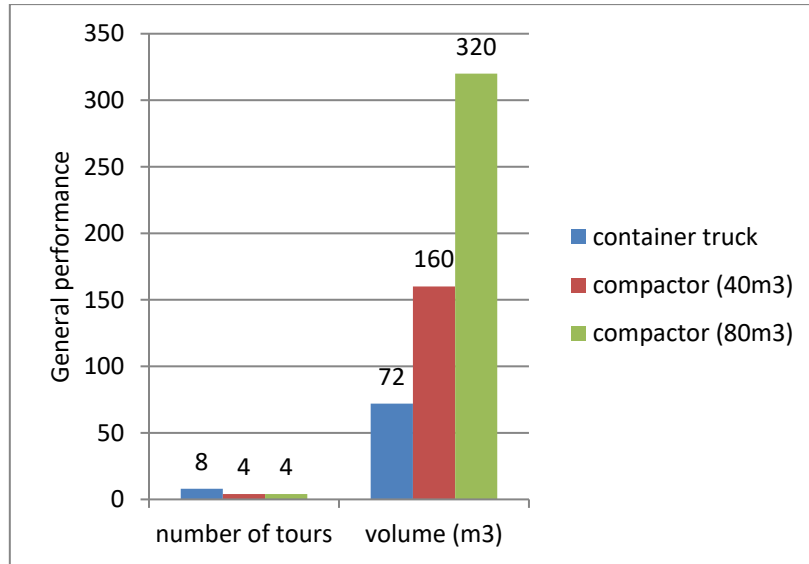


Figure 5-10: General performance during 24hr shift

5.2.2.2 Working hour

During the tracking of trucks, all the activities performed by the workers were observed. The main activities during one shift are summarized in figure 5-10. In general, the longest time was spent on streets, driving to or from container site to the dumpsite. Time was also spent at the container sites/skipping points. The time at the container site depends on the truck type. Container trucks stayed on average 9 minutes at container site, compactors with a volume of 40 m³ stayed 1.5 hrs and compactors with a volume of 80 m³ stayed 2 hrs. The shortest amount of time was spent when the waste was unloaded at the dump site, on average 3 min.

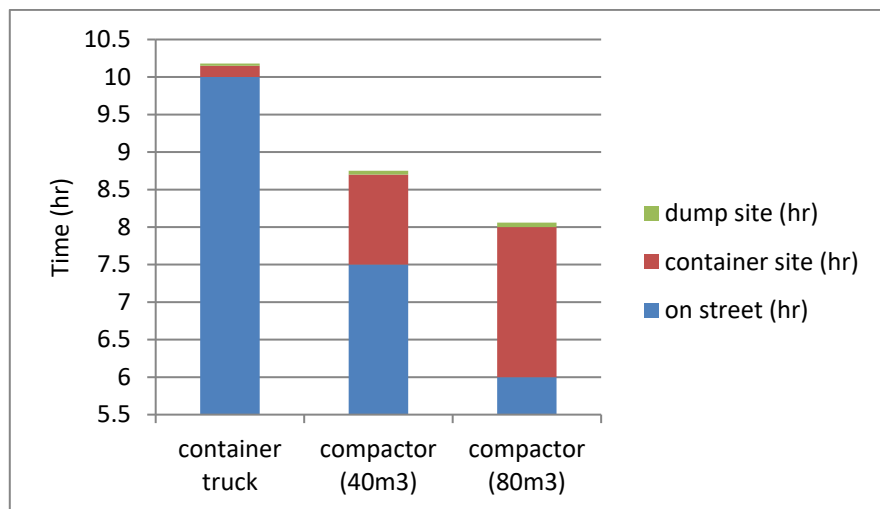


Figure 5-11: Duration of truck activities

5.2.2.3 Truck productivity

The productivity of trucks was determined during the field survey. Truck productivity is defined as the total volume of waste per hour picked up at container sites and dumped at the dumpsite during the working hour. Truck productivity is calculated by dividing the average amount of waste collected during one day with the average working hour. Figure 5-12 shows the volume of waste collected per hour of the different truck types.

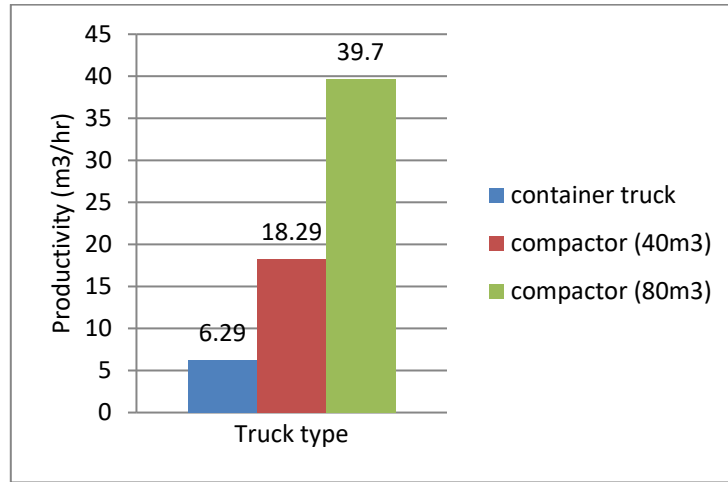


Figure 5-12: Truck productivity

5.2.3 Determination of secondary collection capacity in Addis Ababa

The daily collection capacity estimated the collection capacity that existed at the time of this study, taking into account the number of working hours. The daily secondary collection capacity was calculated using Equation 4.11.

The average working hour per shift and the average productivity per truck type were directly taken from the data received during the tracking of the trucks and which was mentioned above. The number of truck shifts per day was calculated separately for each sub city. Data from interviews at each sub city offices was used about the number and type of working trucks and number of shifts. The collected data is summarized in Table 5-4.

Table 5-4: Working shift of the sub cities

Sub city	Number of trucks in 24 hour shift		
	Container truck	Compactor (40m ³)	Compactor (80m ³)
Akaki Kaliti	8	3	0
Nefass Silk Lafto	11	3	1

Kolfe Keraniyo	5	4	2
Gulele	3	3	2
Lideta	0	1	2
Kirkos	1	1	4
Arada	3	1	4
Addis Ketema	7	3	2
Yeka	5	2	1
Bole	10	3	2
Total	53	24	20

The result from the calculation is summarized in Table 5-5.

Table 5-5: Secondary collection capacity

Truck type	Number of trucks per day	Working hour per shift (hr)	Productivity (m ³ /hr)	Days per week	Annual collection capacity (m ³ /yr)
Container truck	53	10.18	6.29	4	651591.667
Compactor (40m ³)	24	8.75	18.28	4	737049.6
Compactor (80m ³)	20	8.06	39.7	4	1228730.88
Total					2617372.15

The data obtained at the dump site indicates that the amount of waste collected and delivered to the dumpsite during the Ethiopian year 2010 (September 2017 to August 2018) is 2,579,183.22m³. The amount of waste delivered to the dump site starting from September 2018 to March 2019) is on average 220, 110 m³ per month.

5.2.4 Influential factors on truck productivity

5.2.4.1 Truck type

As shown in figure 5-12, the productivity of trucks was clearly influenced by the truck type. Compactors showed the highest productivity because they carried the highest volume. Since container trucks need far less time at container site, they were able to do more tours for the same time line.

5.2.4.2 Manpower

Mainly Compactors productivities were affected by the manpower available for transferring waste. The number of people, their age and physical condition contributed in saving time for transferring waste. Because there is only limited place on trucks for sub city workers to ride on, this job was loaded the on the pre collectors.

5.2.4.3 Design of schedule

During the working hour, the longest time was spent on streets, driving to or from container site/skipping point to the dump site. This in turn affects the trucks productivity. In the night, streets are less crowded with cars and pedestrians. Thus, trucks can drive faster and do not waste time in traffic jam. The result is higher productivity that can be used to collect waste faster than day time. Container trucks are particularly affected by the traffic situation because they cover more no of tours during one shift.

5.2.5 Influential factor on secondary collection capacity

5.2.5.1 Availability of equipment

The number of trucks available for waste collection is a major influence on collection capacity. 31 % of trucks were out of work. The number of trucks available was influenced by the frequency and severity of breakdowns, time for repair and availability of skilled mechanics and spare parts. Furthermore, the number of trucks available in the sub cities is not adequate enough to cover the waste generation rate in the city. According to heads of the cleaning management agency of all the sub cities, the shortage of number of trucks is also their main complaint.

5.3 Waste generation rate of Addis Ababa

5.3.1 Population of Addis Ababa

According to the central statistical agency (CSA), the population of Addis Ababa in 2014 was 3,156,057 with a growth rate of 3.69%. This number of population was projected exponentially to obtain the current population. Accordingly, the current population of the city is 3,795,528.

5.3.2 Waste generation rate in Addis Ababa

Based on the study made by World Bank group on Global Solid Waste Management (2015), the solid waste generation rate per capita for the city Addis Ababa was determined to be 0.86kg/cap/day or 3.26 liter/cap/day. The current solid waste generation of the city was

estimated by multiplying this value with the current population of the city. Accordingly, the current solid waste generation rate of the city is assumed to be 4,157,469.12 m³/year.

5.4 Transfer station design

5.4.1 Site Description

The site of the Solid Waste Transfer Station is located within Lideta sub city, in Woreda 3, next to Lideta manufacturing college. The site is approved to accept waste from the residents of Woreda 1, Woreda 2 and Woreda 3 of the sub city.

5.4.2 Estimation of generated waste

➤ Selection of design period

The design year selected for this project is 10 years. This design year was selected referring to several literatures. The planning horizon for the provision of transfer services at a particular site is recommended to be 10 – 20 years. 10-year design period was selected due to the uncertain nature of estimating the waste generated.

➤ Population projection

The exponential method was adopted to project the population for the design period.

$$P_t = P_0 \times e^{rn}$$

Where; P_t is the design year population

P_0 is the current population

r is the annual growth rate

n is the design period

The annual growth rate was calculated as 3.69% using census of previous years. The population to be serviced by the transfer station is depicted in the table below.

Year		2019	2029
Population	Woreda 1	17,000	24,587
	Woreda 2	7,500	10,848
	Woreda 3	23,875	34,531
Total		48,375	69,966

➤ **Existing generated waste**

Based on the study made by World Bank group in Addis Ababa, Ethiopia (2015), the solid waste generation rate per capita for the city was determined to be 0.86 kg/cap/day or 3.26 liter/cap/day. The amount of solid waste generated in the service area is summarized in the table below.

Year		2019
Population	Woreda 1	17,000
	Woreda 2	7,500
	Woreda 3	23,875
Total		48,375
Waste amount (m³/day)		157.58

➤ **Projected generated waste**

Based on the study made by World Bank group on Global Solid Waste Management (2015), Ethiopia will join the lower middle income economy by 2025 and the solid waste generation rate per capita for the city Addis Ababa is estimated to reach 1.3 kg/cap/day or 4.9 liter/cap/day. The projected waste amount is summarized in the table below.

Year		2029
Population	Woreda 1	24,587
	Woreda 2	10,848
	Woreda 3	34,531
Total		69,966
Waste amount (m³/day)		344.53

5.4.3 Capacity of transfer station

Required capacity of the transfer and transport system is calculated by taking into account that there are 300 working days per year. In year 2029, the required capacity of the system would be 450m³/day.

It should be noted that there is large difference between estimated required capacity of the transfer system and the actual waste collection amount. The data collected during field survey indicates that the current amount of waste collected in the service area is 132.36m³/day but the estimated one is 191.2m³/day.

In order to bridge the difference, it is supposed that the actual waste collection amount would meet with the estimated one with in the design period. Consequently, waste collection amount for designing the transfer system is summarized in the table below.

Year		2019	2029
Population	Woreda 1	17,000	24,587
	Woreda 2	7,500	10,848
	Woreda 3	23,875	34,531
Total		48,375	69,966
Waste amount (m³/day)		157.58	344.53
Required capacity (m³/day)		191.72	450

5.4.4 Transfer technology

The type of transfer station recommended for the transfer and transport system is the ‘tipping floor waste storage’ system. As introduction of the transfer station is the first case in Addis Ababa and it is expected to expand the facility, the system should be simple to operate and the facility be flexible. This system has Simple arrangement (little potential for equipment breakdown). It is generally less expensive and provides more operational flexibility. The storage provides disconnect between waste receipts and waste loading i.e. shortage of transfer trucks does not shut down facility. In addition it allows easy screening and removal of unacceptable wastes.

5.4.5 Conceptual design

➤ Outline of the project

The project is outlined in Table 5-6.

Table 5-6: Outline of the project

Item	Specification
Transfer station	Type: Tipping floor waste storage Capacity: 450m ³ /day
Collection equipment	Push cart Collection capacity: 1.24 m ³ Dimension: 1.5x1.18x0.7 (LxWxH) Truck Collection capacity: 4.5 m ³ Dimension: 2.7x1.5x1.1 (LxWxH)

Transport equipment	Compactor truck Collection capacity: 40m ³ Dimension: 6.4mx2.05mx2.57m (LxWxH) Compactor truck Collection capacity: 80m ³ Dimension: 7.3mx2.2mx2.7m (LxWxH) Wheel dozer Dimension: 7.4mx3.3mx3.5m(LxWxH)
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➤ **Conceptual design**

Figure 5-13 shows the proposed site lay out plan of a fully enclosed transfer station and Figure 5-14 shows the main transfer building. This facility has a design capacity of 450 m³ per day. The Site design plans show the following features:

The transfer station building. Including tipping floor (the floor of the transfer station where waste is unloaded (tipped) for inspection, sorting, and loading.

Parking areas. Employees, visitors, and transfer vehicles.

Buffer areas. Open space and trees that reduce impacts on the community.

Access roads. Instance and exit of vehicles

Materials Recovery area: Plastics, paper, and metal

Utilities. Wash room, toilet

Guard house: Guards shelter

Store: sanitary equipments, pesticides

Office

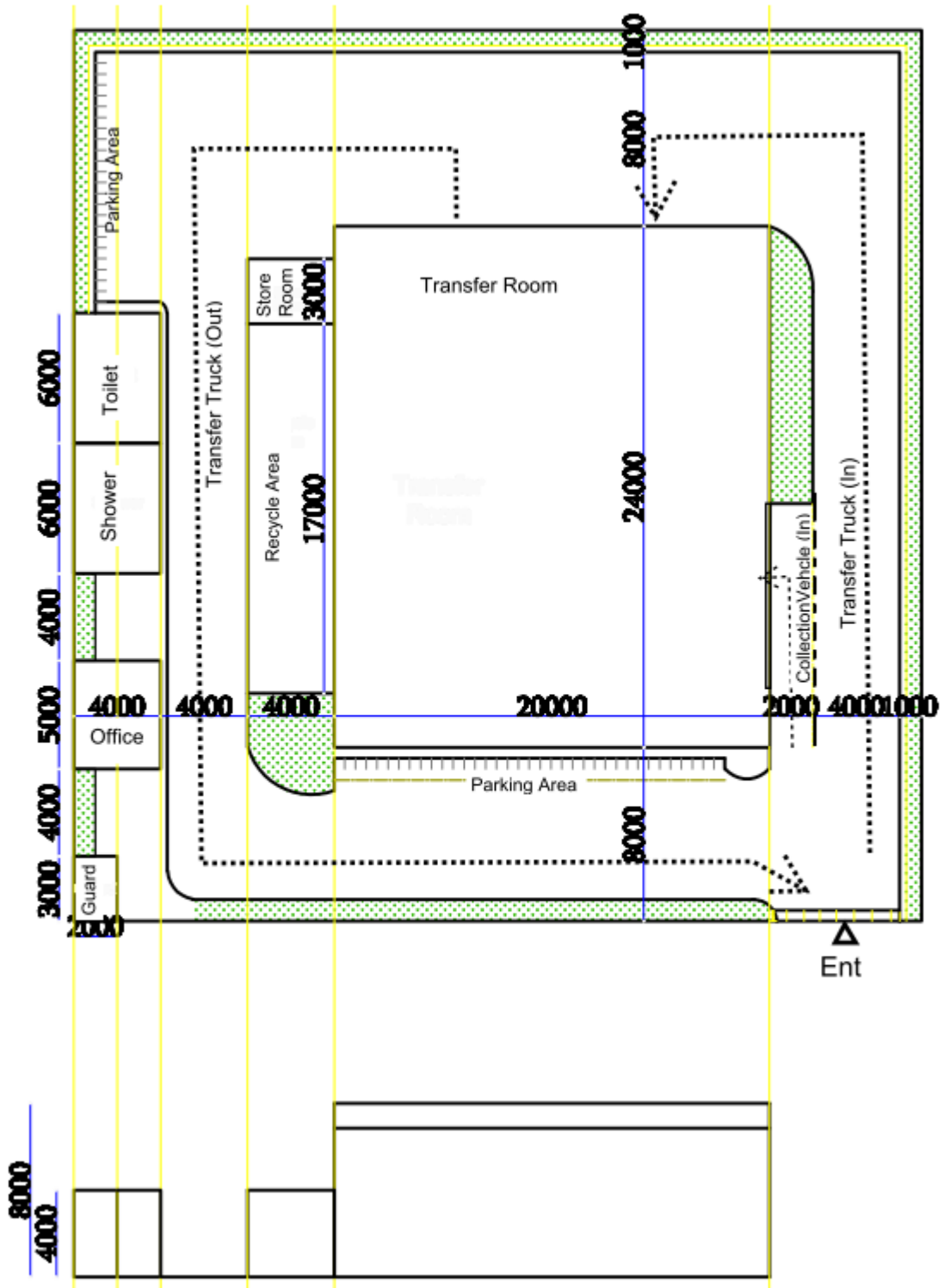


Figure 5-13: Plan of transfer station

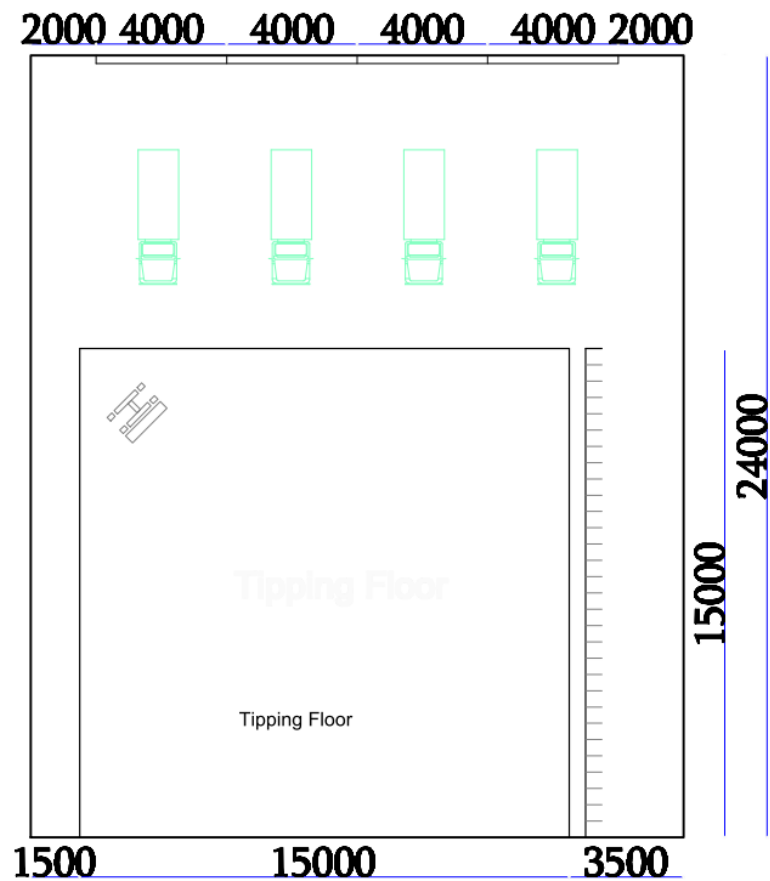


Figure 5-14: Main transfer building floor plan

5.4.6 Nuisance Management

➤ Litter

Litter management includes:

- Storage of waste and recyclable materials in containers and/or buildings as intended in the design
- Require all incoming and outgoing loads to be covered.
- Ensure that all incoming and outgoing trucks are leak-proof to avoid leachate spills on public streets.
- Implement daily litter inspections and pickup at the facility and on surrounding streets.
- Install a perimeter fence to prevent windblown litter from leaving the site.
- Retrieval of litter on the site, surrounding properties, and along roads leading to the site.

➤ **Dust**

Management of dust includes:

Dust from Vehicles

- Pave all roads on site, or lay gravel as a less expensive option.
- Clean facility roads frequently with street-sweeping equipment.
- Wash waste collection vehicles before they leave the transfer station to remove dust-generating dirt and debris.

Dust from Waste Handling Operations

- Align building openings to minimize exposure to prevailing winds.
- Install plastic curtains over building openings.
- Keep station doors closed during operating hours, except when trucks are entering or exiting.
- Install misting systems over tipping areas to “knock down” dust particles.

➤ **Odors**

Odor management includes:

- Remove all waste at the end of each operating day. Do not allow any waste to remain on site overnight.
- Frequently clean/wash down the tipping floor or surge pit.
- Install ventilation systems with air filters or scrubbers.
- Plant vegetative barriers, such as trees, to absorb and disperse odors.
- Install plastic curtains on entrances and exits to contain odors when doors are opened to allow vehicles to enter or exit.

➤ **Noise**

Mitigation of noise includes:

Structural and Site Layout Approaches

- Totally enclose all waste-handling operations to contain noise.
- Use concrete walls and structures, which absorb sound better than metal structures.
- Install double-glazed windows which contain noise better than single-glazed windows.
- Install shielding or barriers, such as trees and walls, around the facility to block and absorb noise. Size of the shielding, distance to receptors, and shielding materials all determine

effectiveness. Walls can be made from concrete, stone, brick, wood, plastic, metal, or earth. Vegetation further mitigates noise and increase aesthetics. Barriers should be continuous, with no breaks, and long enough to protect the intended receptors.

- Insulate transfer building walls with sound-absorbing materials.
- Locate administrative buildings between sources of noise and community.
- Orient transfer building openings (i.e., doors) away from receptors.

Operational Practices

- Keep doors closed during operating hours, except when vehicles are entering or exiting.
- Establish operating hours that avoid early morning or late night operations.

➤ **Vectors**

The control of vectors such as rats, mice, cockroaches, and other insects include:

- Seal or screen openings that allow rodents and insects to enter the building, such as door and window frames, vents, and masonry cracks. Also check for and repair chewed insulation at points where utility structures, such as wires and pipes, enter the transfer building.
- Treat insect breeding areas and eliminate as many of these breeding areas as possible. Implement practices that do not create new breeding areas.
- Implement practices that reduce the likeliness of attracting vectors (e.g., remove all waste at the end of the operating day, wash tipping areas daily, and pick up litter and other debris daily).

Chapter 6 CONCLUSION

6.1 Summary and conclusion

Municipal solid waste management (SWM) is one of the most important tasks that have to be carried out by the government. Collection of municipal solid waste is the most important aspect of solid waste management. Of the total expenditure incurred in solid waste management, typically 70 to 80 percent is directed towards the collection and transportation of waste. The term “solid waste collection” is taken to include the initial storage of waste at the household, shop or business premises, the loading, unloading and transfer of waste, and all stages of transporting the waste until it reaches its final destination – a treatment plant or disposal site. Waste transfer stations play an important role in a community’s total waste management system, serving as the link between a community’s solid waste collection program and a final waste disposal facility. This study is focused on assessing the solid waste collection system in Addis Ababa. Accordingly, the productivity of the primary and secondary waste collection system of the city was determined, and the influencing factors on the collection capacity were identified.

The primary waste collection is conducted by pre collector groups. In average one pre collector group consists of 10 workers. The pre collectors serve areas in a door-door collection. Majority of the groups (65%) collect the waste by using pushcart while the rest use collection truck. Concerning the collection mechanism, three different methods were identified: the pushcart method, the pushcart - collector method, collecting truck method. The average collection productivity of each collection method was determined to be 2.12m³/worker/day for the pushcart method, 2.81m³/worker/day for the pushcart - collector method and 4.2m³/hr for collection truck method. In the secondary collection system, three different types of trucks were used to deliver waste from the container sites to the dumpsite: container truck (8 m³), compactors truck (40 m³) and compactors truck (80 m³) with collection productivity of 6.29 m³/hr, 18.29 m³/hr and 39.7 m³/hr respectively.

The primary waste collection capacity of Addis Ababa is determined to be 3192868.8m³ /year and the secondary waste collection capacity 2,579,183.22 m³/year. This value show that the current solid waste collection capacity of the city is lacking when compared to the waste generation rate of the city which is 4, 157469.12m³/year.

The major possible influential factors that affect productivity in primary waste collection were collection methods, equipment used, and motivation of the workers. For secondary waste collection, the factors that affected productivity were truck type, manpower, design of schedule and availability of equipments.

It was also observed during field survey that the city is in need of a safe, operationally efficient transfer facility that meets the waste needs of the community. In many communities, citizens have voiced concerns about temporary solid waste storage sites that are poorly sited and operated. The current atmosphere is such that gaining public approval for constructing new facility near population center is challenging.

6.2 Recommendation

The current solid waste collection of Addis Ababa doesn't cope with the waste generation rate of the city. Therefore there is a need to address the issue.

The overall collection capacity of the city can be enhanced by promoting the use of best practices in transfer station sitting, design, and operation to maximize the collection system effectiveness and efficiency, while minimizing the impact on the community.

In addition to regulatory requirements, public opposition frequently makes sitting a new transfer station near population centers difficult. Yet transfer stations play an important role in a community's waste management system. A sitting process that includes continuous public participation is integral to developing a transfer station. The public must be a legitimate partner in the facility sitting process to integrate community needs and concerns and to influence the decision-making process.

For publicly developed transfer stations, a good first step by public officials in the site selection process is establishing a sitting committee. The committee's main responsibility includes developing criteria to identify and evaluate potential sites. The committee should consist of key individuals who represent various stakeholder interests. These stakeholders might include:

- Community and neighborhood groups
- Industry and business representatives
- Civic and public interest groups
- Environmental organizations
- Local- and state-elected officials

- Public officials, such as public works employees and solid waste professionals
- Academic institutions

Committee members should be selected to ensure broad geographical representation from across the area to be served by the transfer station. The government agency responsible for transfer station compliance also should make a commitment to the community concerning its role in actively and effectively enforcing all requirements.

In addition, the productivity of primary waste collection can be enhanced by improving the pre collectors' equipments. The equipments the pre collectors work with are expected to be provided by themselves. Therefore there is limitation in capacity to the type, number and state of the equipment they can work with. The working environment could also be improved by providing them with safety equipments such as gloves and face mask for mouth and nose. This would protect the health of the workers and the collection process would get more effective, increasing their productivity.

To improve the productivity and capacity of secondary waste collection, the sub cities can practice regular maintenance of trucks. This leads to less number of trucks out of work in the future. The number of trucks available for waste collection should also be increased for all the sub cities to fit the collection capacity of the pre collectors. Furthermore, it was observed from the study that compactors have overall better collection capacity when compared to container trucks. Therefore the operation system should focus more on compactors. The sub cities could also use incentives such as extra money to motivate drivers and assistants to operate more shifts.

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APPENDIX

Assessment of the Solid Waste Collection Practices of the City Of Addis Ababa

Addis Ababa Institute of Technology

Proposed key informant

CMA at the woreda

- Cleansing management officer

CMA at the sub city

- General manager of solid waste management
- Environmental protection officer

CMA at the city

- Head of the solid waste management

Head of the selected pre collector groups

Truck Drivers

Appendix I - Semi Structured Interview Guide: CMA of the Woredas

Questions	Response
1. How many pre collector groups work in this woreda in total?	
2. How many members in average are in one group?	
3. How many households are in the woreda?	
4. Which criteria are decisive for the division of the collection areas?	
5. Who decides how many pre collectors are in one group?	

Appendix II - Semi Structured Interview Guide: Pre Collectors

Questions	Response	Supplementary questions
1. How many members are in your group?		How many females are there?
2. What equipment do you have?		Who provide you with the equipment?
3. Where do you bring the collected waste?		
4. Container		
a. How many containers do you work with?		
b. How long do you need to fill a container?		
c. How often are the containers collected?		
5. How many days per week do you work?		
6. How many days per week do you serve one area?		

Appendix III - Semi Structured Interview Guide: CMA at the Sub City

Questions	Response	Supplementary questions
1. How many woredas are in the sub city?		
2. How many SME's are in the sub city?		
3. Container		
a. How many container sites are in the sub city?		Is there a map?
b. How many containers are collected per day?		
4. Trucks		
a. How many trucks are there?		How many are in operation?
b. What types of trucks are there?		
c. Where are the trucks starting from?		
5. How many days per week does the trucks operate?		
6. What are the working hours?		The number of shifts?
7. How many people are working on one truck?		Is there a place for extra person?

Appendix IV - Semi Structured Interview Guide: Drivers and Assistants

Questions	Response	Supplementary questions
1. How many people usually work in one truck?		
2. What are your responsibilities?		
3. How many days per week do you work?		
4. Do you always work on same truck?		Do you always work together?
5. Do they drive to the same container site every day?		
6. How often do the trucks be maintained?		

Appendix V - Monitoring Sheet for Pre Collectors

Date		Start time	
Sub city		Arrival container	
Woreda		End transfer	
Pre collector			

Stop no.	Stop	Start	Households	Bags	Workers
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Appendix VI - Data Collection Sheet of the Trucks

	Time	Location
Start of work		
End of work		

At the Containers sites

No	Arrival time	Departure time	Area of container site	Transferred volume (m3)	Sources of waste	Pre collector groups that serve the container
1						
2						
3						
4						
5						

At the dump site

No.	Arrival time	Departure time	Transfer start	Transfer end