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REVERSE LOGISTIC NETWORK DESIGN AND ANALYSIS FOR PLASTIC BOTTLES

(CASE STUDY IN DIRE DAWA CITY).

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REVERSE LOGISTIC NETWORK DESIGN AND ANALYSIS FOR PLASTIC BOTTLES (Case Study: - In Dire Dawa City).

By Getu Girma

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This is to certify that the thesis prepared by **Getu Girma,** entitled **Reverse logistic network design and analysis for plastic bottles** and submitted in partial fulfillments of the requirements for the degree of Master of Science (Mechanical and Industrial Engineering) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Declaration

I, Getu Girma, declare that the Masters research thesis entitled "***Reverse logistic network design and analysis for plastic bottles A case study in Dire Dawa City***" is my original research work and no material has been submitted previously for the award of any other academic degree.

The research work was done under the guidance of Dr.-Ir Kassahun Yimer and Wogene Tesfaye (PhD Candidate), at Addis Ababa university, Addis Ababa Institute of Technology in School of Mechanical and Industrial Engineering.

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This is to certify that the above declaration made by the author is correct to the best of my knowledge.

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Abstract

Currently, the concept of reverse logistic is attracting due attention due to the developmental agenda of environmental sustainability and related economic advantages obtained through recycling and reuse of resources. One of the challenges in reverse logistics has been the lack of appropriate framework for analyzing and designing reverse logistic of used products such as plastic bottles. In this study, the design and analysis of reverse logistics in Ethiopia taking a case of Dire Dawa city has been conducted. Dire Dawa city has been affected due to huge volumes of plastic bottles being dumped in the surrounding environment. This has led to several environmental problems and has a negative influence on the drainage system of the city. It has also influenced the beauty of the city and created dreadful image of the city as plastic is not easily decomposed by its nature. Therefore, this thesis focused on analyzing and designing effective reverse logistic system for plastic bottles in the aforementioned case. To achieve the research objectives, a literature review was conducted so as to develop the clear concept of reverse logistic, its activities, processes, networks, challenges, barriers affecting implementation of reverse logistic and provided an overview on plastic bottle recycling. Appropriate data required for the case study were collected using primary and secondary sources. Using the data collected, a linear programing problem was solved by **LINGO 17.0** programming software and the solution attained were used to design to minimize total transportation cost of the truck, during the collection of plastic bottles from the destination. The performance of the truck route and proposed network was analyzed using **Arena 14.50.00002** simulation software. The research followed three scenarios for truck route in the collection of plastic bottles from all destinations in the city. The baseline for scenario was taken as the current practice in the city. Based on the scenario analysis, around **3,585 ,893.5** plastic bottles/week was collected and made ready for recycling. Following these data, the estimated monthly financial revenue to be generated would be around **$160,297.824**. Hence, the study found out that such amount of opportunity can be exploited if appropriate design of reverse logistics networks can be developed**.** In the study, it is recommended that the government bodies/top management should work on organizing and supporting the informal sectors which are work on recycling of plastic bottles and create awareness for the community on how to separate plastic bottles from other organic waste at home levels. Further research areas are also indicated in the study.

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Abbreviations

RL: - Reverse logistics

RLS: - Reverse logistics system

RLND: - Reverse logistics Network Design

EPA: - Environmental Protection Authority

ISWM; - Integrated Solid Waste Management

UNIDO: - United Nations Industrial Development Organization

UNEP: - United Nations Environment Program

EFBW: - European federation of bottled waters

SME ‘s: - small scale and micro enterprises

CC: - Collection Center

Ts: - Temporary storage

LP: - linear programing

DRN: - Direct reuse networks

RMN: - Re- manufacturing networks

RSN: - repair service network

ISM: - Interpretive Structural Modeling

AHP: - Analytical Hierarchy process

ANP: - analytic network process

CHAPTER ONE

1. Background of the study

1.1 Introduction

It can be observed that the culture of Ethiopian society in drinking bottled water at home, work place, recreation and travel in and outside the country has been changing from time to time. This change of culture has provided another opportunity for Ethiopian water bottling companies to sell their products in the local market and in the international market as far as international water quality standards are met. However, the trends of revers logistic for plastic bottles was so low in the country. And many organizations do not understand what procedures to follow and how to manage and implement plastic bottles reverse logistics efficiently (Hailu 2017).

European countries have been the leading countries in product recovery and recycling management. Whereas, developing countries including Ethiopia have no common practice and lack framework or system designed for reverse logistics program in recycling or reusing plastic bottles products. According to Bernon eta al. (2011) reviews, if reverse logistic managed correctly manage and minimizing transportation costs, it improves revenue. Since, effective reverse logistics management can add significantly to an organization's profitability through providing economic and environmental benefits. Economic benefits that obtained from reverse logistic was, create additional jobs by recovering industry and reducing disposal costs (Morris 2015).

Generally, as some researcher over viewed, revers logistic for plastic bottles makes both environmental sense and economic sense. More or less, the environmental benefits of reverse logistic has been over viewed, mostly focusing on the assessment of environmental aspects.

But, this research has tried to focus on the **economic side** of the recycling of used product and demonstrated that recycling makes economic sense for new economic starter, small and micro enterprises, institutional and governmental sectors.

1.2. Statement of the problem

Currently, Plastic Solid waste management has been a big challenge to both developed and developing countries all over the world. It was a hot issue in to days in global aspects. This problem still continues to get public health importance.one of the main constraints in waste management of developing country is lack of awareness of the people about waste management. It was needed that to aware people, the fact that plastic waste could be recycled to providing organic fertilizers, tools, and devices

According to Joseph (1973) reviews, Europe countries were the leading through recycling especially on the area of plastic products. But among all countries, China is the most leading countries through recycling capacity of around 56% of plastic product is easily recycled. Plastic bottles waste poses a serious problem in municipal solid waste management as they are practically non-biodegradable. Even this, plastic products have a very negative influence on the drainage system of the city. It also has influence on the beauty of the town, health of cattle, moisture content of land and also on political, economic, social-cultural and technological dimension (Tomsons 2007).

In Ethiopia, there is no good practice of plastic waste reduction through recycling and composting except the informal recovery of plastic waste by poor people. Especially these days, practice in Dire Dawa city regarding to plastic waste management has been simply collecting all types of waste materials in a container and then dumping them out of the city, without any proper treatment which can be the source of severe health hazard to people, animals and environment in general (Morris 2005).

According to Hailu (2013) reviews, Dire Dawa city is characterized by rapid population growth caused by natural increase and migration from rural area. The population of the region is at present estimated to be about **369,674** of which **73.6%** reside in the urban area and the rest **26.4%** live in rural areas (Hayal et al. 2016). Such rapid increase in population together with rapid development of the city has produced increasing volumes of plastic solid waste and in turn it induced greater infrastructural demand, institutional setup and community participation for its management. But, the city sanitation and improvement which runs the solid waste management activities of the town could not fulfill the above requirement.

Dire Dawa has a hot semi-arid climate (Koppen climate classification). The mean annual temperature of Dire Dawa is about 25.9 °C or 78.6 °F. The average maximum temperature of Dire Dawa is 32.8 °C or 91.0 °F, while its average minimum temperature is about 19.0 °C or 66.2 °F. The region has two rain seasons; that is, a small rain season from March to April. More pronounced rain season that extends from July to August. The aggregate average annual rainfall that the region gets from these two seasons is about 583 millimeters or 23.0 inches (Hailu 2013).

Due to environmental condition, beverage consumption is generally high leading to an increase in consumption of plastic bottles in Dire Dawa city. Even this, there is no appropriate reverse logistic system that can be designed for collection of plastic bottles in stated case. Which cases, huge volumes of Polyethylene Terephthalate (PET) bottles are deserted on the Environment. Due to all these cases, there was some problem that suffered Dire Dawa city.

- Lack of properly designed collection system that reach in accessible collection areas to reach every part of the city (Hailu 2013).
- Currently, there was no enough garbage tank that design for collecting plastic bottle in Dire Dawa city
- Low level of participation of the private sector, small and micro-enterprises that can create that much difference in plastic bottle waste management.
- Environmental impacts Pollutants released from burning plastic waste due to: -burning as wastage and environment pollution.
- There is no strong adequate system design for reverse logistic in such area.
- Lack of proper direction and promotion in the areas of waste minimization, waste reduction, recovery, reuse, recycling, composting, burning waste and sanitary landfill.
- Lack of research and solution-oriented studies on this area (Fetsum 2000)
- Shortage of modern trucks, equipment and materials in sufficient number and type for storage, collection, transfer, transportation, disposal, recycling, composting, incineration (proper burning wastes) and street sweeping (Fikru 2001).

1.3. Objectives

1.3.1 General objective

The general objective of this study is to analyze and design effective reverse logistic system for plastic bottles in Dire Dawa city.

1.3.2 Specific objective

- To understand Reverse Logistic activities and practice of plastic bottles in Dire Dawa city.
- To identify the dominance barriers that affecting the implementation of Reverse Logistic of plastic bottles in Dire Dawa city.
- To propose best plastic bottles, Reverse Logistic network model that used to improve the collection system and economic beneficiary from recycling of plastic bottles in Dire Dawa City?

1.4. Research Questions

Following the problem above, this research is therefore expected to answer the following questions:

- What are the main practices and activities taking place in Reverse Logistic of plastic bottles in Dire Dawa city?
- What are the major barriers that hinder or prevent the implementation of Reverse Logistic of plastic bottles in Dire Dawa city?
- What types of Revers Logistic network model should be used to design, in order to improve the collection system and be beneficiary of economic advantage of plastic bottles in Dire Dawa City?

1.5. The Scope of the Study

This research is limited to reverse logistic network design and analysis for plastic bottles in Dire Dawa City. The data for the analysis would be collected from micro and small-scale enterprises organized in collecting solid waste and plastic bottles in Dire Dawa city, From Copa Impact PLC plastic bottles recycling company, Addis Ababa solid waste management and cleaning agency. Finally, this study does not include varieties of plastic solid wastes including soft drink plastic bottles other than water plastic bottles.

1.6. Significance of the Study

This study is important in several aspects for several stakeholders. Firstly, the findings of this research will serve as inputs to used plastic bottles recycling companies in Dire Dawa city, bottled water and soft drink producing companies, city administration, city sanitation and beauty agency will be the partially beneficiary of this research. Lastly small and medium enterprise and small business startup to generate economic advantage easily and all Dire Dawa city community through being free from environmental contamination.

1.7. Limitation of the study

Currently reverse logistics system is a new concept which not previously applied correctly in Ethiopia, Especially in on plastic bottles recycling process. Data's are limited for model validation and most bottling companies were not willing to give data needed. The main limitations include, lack of data on the number of plastic bottles wasted in Dire Dawa city, fixed cost and variable costs for optimizing truck routs in collecting plastic bottles for proposed network. Therefore, the study has conducted with limited data, a preliminary survey and considered an observation of stated case and interviewers was some the means of collecting data for the study. However, the limitation does not affect the end result or the quality of the research addressed within the scope.

1.8. Organization of the Thesis

The Thesis is organized into five chapters. The first chapter gives introduction and overview on the general background and justification of the study problem. The second chapter deals with a literature review of the concept of reverse logistics, process and activities of reverse logistics, plastic recycling global trading capacity, reverse logistics network characteristics, Most Barriers that affect the implementation of reverse logistic and finally presents the literature gap and summery. The third chapter focus on the methodology and research design to give a clear view on the direction of the research design used in the study. Chapter four, data analyze and data interpretation parts, reverse logistics network model assumption and the results of the model was presented. Lastly, chapter five covers the conclusion and recommendation of the study.

CHAPTER TWO

2. Literature Review

2.1 Overviews of Plastic Solid Reverse Logistic System

Plastic solid Waste management is a current, complex subject. All most all human activities that practice in his daily movements/ activities create plastic solid wastes. The amount of plastic solid waste created increased fundamentally around the world. Not only increased in amount but also in a type and toxicity. Plastic solid Waste management is a hot issue today in most countries around the world. Plastic Waste management in an any country is directly or indirectly it must have related to economic, social and political status of the country (Srivastava 2006).

In Ethiopia, like other developing countries, the increasing of plastic solid waste generation is resulted from rapid urbanization and population growing. Plastic is a major trouble in municipal solid plastic waste as it pollutes the environment, difficult to decompose, close drains, and causes flooding during the rainy season. Today, it obesely seen that there is a growing demand for water bottling consumption in the worlds. So, this cases a radical change to increase the number of plastic bottles that dumbing here and there in illegal ways. Therefore, Plastic waste collection and recycling bring about multiple social, economic and environmental benefits (Rogers 2016).

According to Charles (2017) Plastic creates toxic pollution at every stage of its existence, manufacture, use, and its disposal. In its nature plastic is a material that difficult to decomposed and the Earth cannot digest. Even this, the trends to use revers logistic for plastic bottles in developing country was so low when comparing to other developed counties. So, this research will try to review the definition of Revers Logistic from different books and journals, the environmental benefits, activities, environmental policies related with Revers Logistic and corporate social responsibility of water bottling companies in Dire Dawa city would be reviewed.

2.2. Definitions of reverse logistic

Many organization and individuals have tried to define the term Reverse Logistics.as per there definition's, reverse logistic is all activity that associated with a product/service after the point of sale, the ultimate goal to optimize or make more efficient aftermarket activity, thus saving money and environmental resources (Pienaar 2002).

According to Carter (2014) and Rogers &Tibben (1998) the term Reverse logistic stands for all operations related to the reuse of products and materials. It is the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value.

More accurately, reverse logistic is the process of moving goods from their typical final destination for the purpose of capturing value. Mostly the term RL deals with four basic views Reduce, substitution, reuse and recycle. The operations of reverse channels of distribution are receiving increased attention as general solid waste pollution, frequent energy shortages, and serious materials scarcity are recognized as realities of our modern age (Jefferson 2009). According to Jayaraman and Raymond (2001) any companies are to survive in this modern period, they will have to plan, organize and manage specifically for environmental, energy and materials contingencies.

Manufacturing and refurbishing activities also included in the definition of RL as may authors' reviews. The reverse logistic process includes the management and the sale of surplus as well as returned equipment and machines from the hardware leasing business. Normally, logistic deal with events that bring the product towards the customer (Mohamad 2014). In the case of reverse logistic, the resource goes at least one step back in the supply chain. For instance, goods move from the customer to the distributor or to the manufacturer.

According to Richard et al. (2012) defined RL as, the processes of receiving returned components or products for the purpose of recapturing value. Reverse logistics processes and plans rely heavily on reversing the supply chain. So that, companies can correctly identify and categorize returned products for disposition, an area that offers many opportunities for additional revenue.

Most authors define the term RL as all activities associated with product or service going from upper stream to lower stream and from lower stream to upper stream in order to optimize ultimate goal and make more efficient for market activity. Reverse logistic includes all of the activities that are mentioned by some researcher in the above. The difference is that reverse logistic encompasses all of these activities as they operate in reverse.

Adopted all above definition, reverse logistics is the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in –process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value.

2.3. Types of Reverse Logistic System

The objective of developing framework for RL is a means to suggest a basis for implementing or reviewing a RL system. Any cases there are two types of RL systems, which is confidential based on the degree of the openness and in its nature of the network type.

a. Closed loop RL system
b. Open loop RL system

2.3.1. Closed loop system

According to Rosani (2013) reviews, closed loop system is a process in which the waste or by product of one process or product is used to returned for other products in order to making another product or derived component in its theory. This process can be used for certain period of time without introduction of other virgin materials. In this process, used products return back to the original companies or the producers as shown in the figure below.

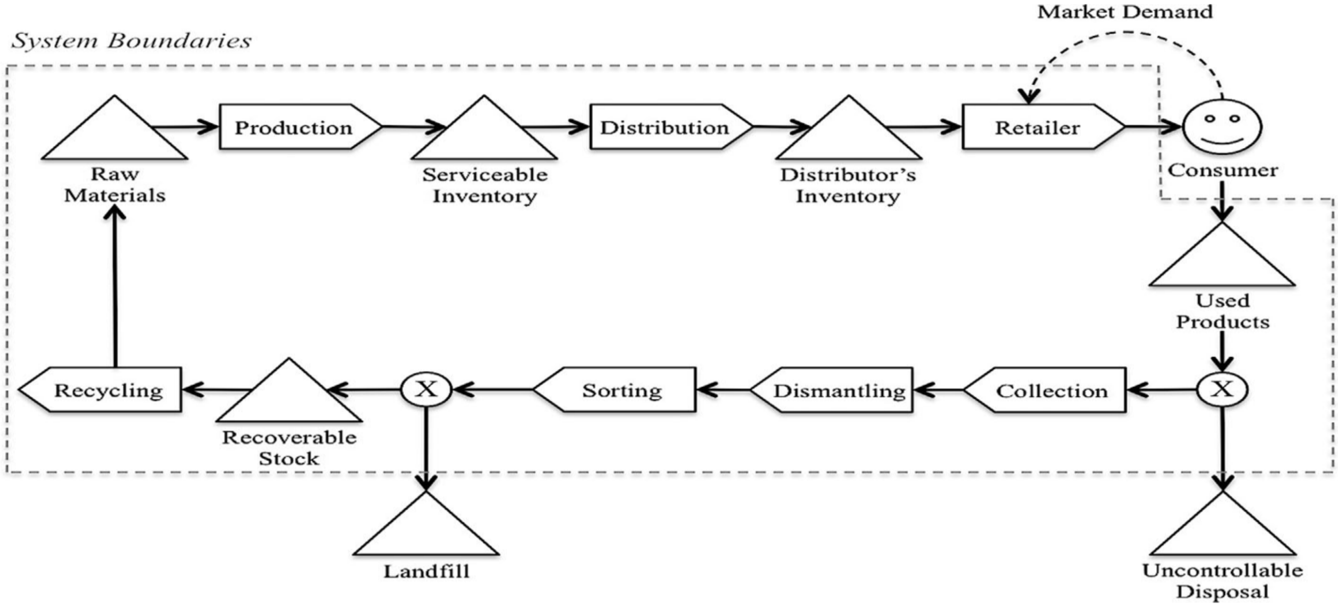

Figure 1 Closed loop reverse logistic system

[Source: Re-arranged from Srivastava (2008)]

2.3.2. Open loop system

In this case, it is a process in which Recycling system for product made from one type of material is recycled into a different type of product. This occurs normally in postconsumer materials. In this process, different products and manufacturers may be involved.

Figure 2 Open loop Reverse logistic system

(Singh, Singh and Walia, 2011)

2.4. Reverse Logistics Activities

In cases, common activities that cautious with reverse logistic is: - logistics, warehousing, repair, refurbishment, recycling, e-waste, after market call center support, reverse fulfillment field service and many others (Parviz 2016). Reverse logistics is the term commonly used to describe end of life product management. This means that reverse logistics is mainly concerned with return or take-back products and materials from the point of consumption to the forward supply chain for the purpose of recycling, reuse, re-manufacture, repair, refurbishing or safe disposal (Farris 1992). In both cases the term Reverse logistics focuses on getting product back from customers rather than moving products to customers.

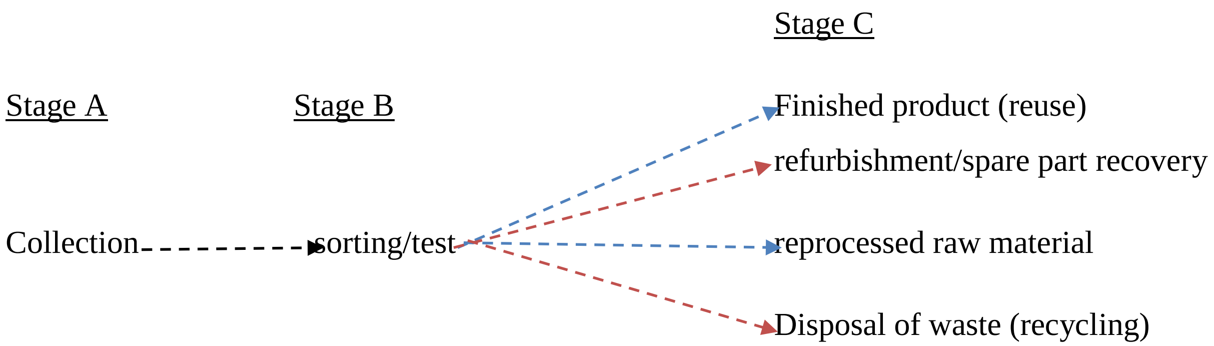

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Figure 3 flow of reverse logistic activity

Reverse logistics activities can be performed to take back the product itself as well as its packaging. According to Rogers and Tibben (2001) differentiated between reverse logistics activities for products and packaging. For products, the common reverse logistics activities are: refurbishing, re-manufacturing, recycling, reclaiming materials, returning to supplier, salvaging and disposing in landfills (Zailani 2001).

The common reverse logistics activities are reuse, refurbish, and reclaim materials, recycle, salvage and landfill. This means that re-manufacturing is rarely performed for packaging activities start with collecting end-of-life products. (Christensen 2002).

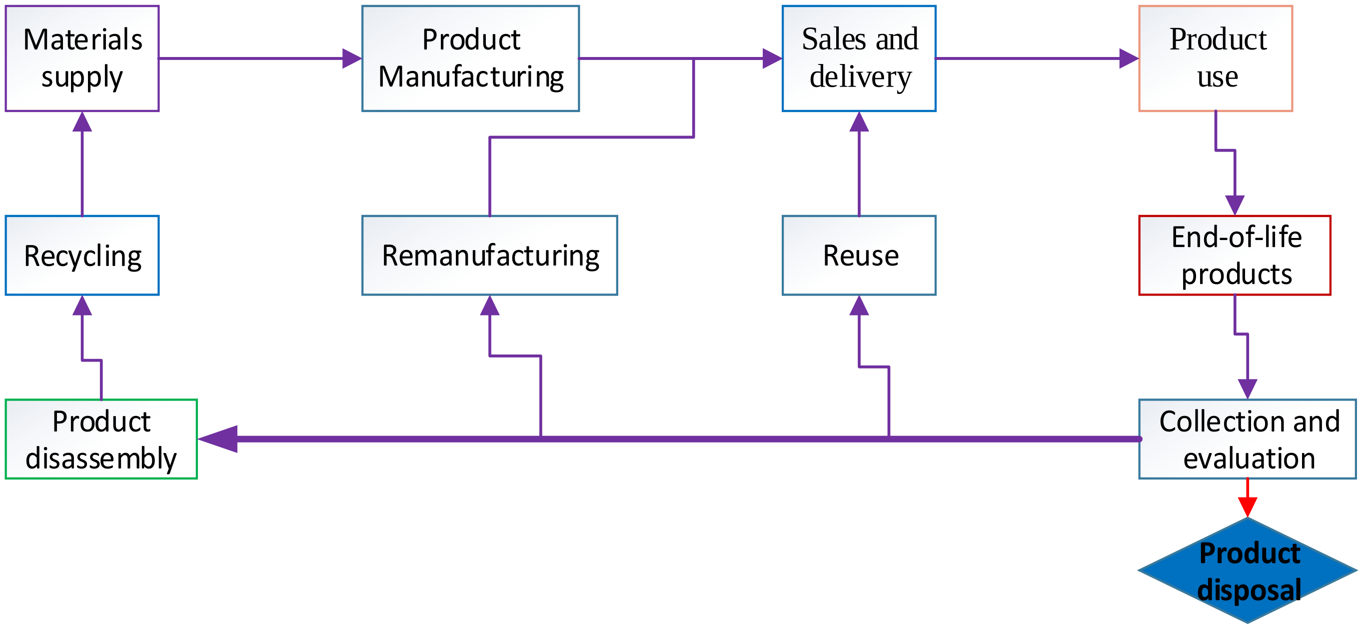


Figure 4 plastic bottles recycling activities

(Adapted from Geyer and Jackson (2004, p.57)

2.5 Waste management hierarchy

The waste management hierarchy shows, the ranks in different ways of dealing with waste in order of desirability. At the top is waste reduction, which means not generating waste in the first place or minimizing the amount of waste produced. Below that is waste reuse followed by recycling (processing of wastes into new raw materials). A fourth option is the recovery of energy by burning or biological treatment. Disposal, ideally in a landfill site, is the final option for any wastes that cannot be dealt with in any other way. A landfill site is an area of land set aside for the final disposal of solid waste (Joseph 1973).

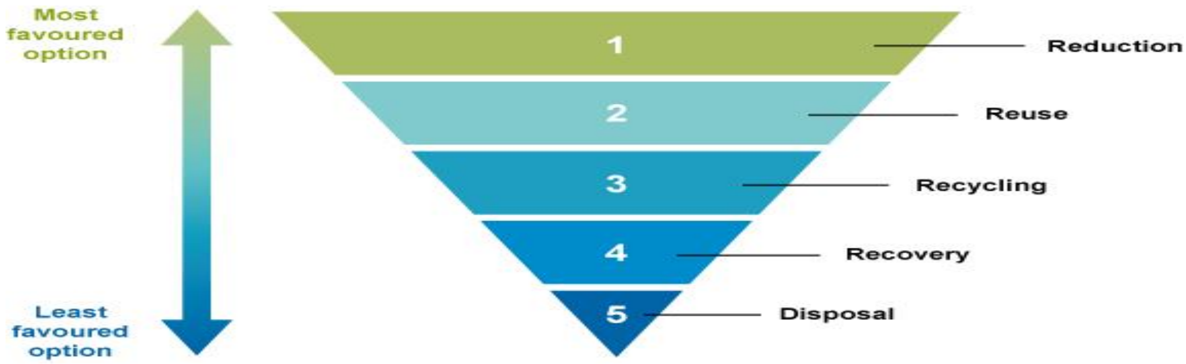


Figure 5 waste management hierarchy

Source; - IGNIS, Waste Management Hierarchy 2014

Reduce: -Reduce means, a process of reducing producing of wastes at the sources and managing the generation undesirable items at source, i.e. reduce become noteworthy. Waste reduction measures have the potential to raise the awareness of the community and other stakeholders, control the generation of waste, and improve the quality of recyclable resources. (Toshima 2013)

Reuse: -Reuse is a process of using materials more than once through extending the life of the products or giving a second life to something that we previously considered as "garbage".it is a process of thinking before deciding that we're missing a product/object (Feacham 1998).

Recycling: -it is a process in which making new products from used materials. Like reuse, recycle means recovering an object and giving it a second life. While reusing an object means using it without really modifying it or favoring multi-purpose objects and products over single-use ones, recycling means bringing an object back to a state of raw material (Matteo 2015)

Recovering: -Most of the materials thrown in the garbage can be used and processed in ways other than being destroyed. Reusing, recycling and composting are the most frequently used methods for recovering waste. Another alternative is recovering the energy stored in residual material. That means turning waste into a fuel for manufacturing processes or equipment designed to produce energy (Heijboer 2009).

Disposal: - which is the last desirable option or solution. Things which throw away as garbage after used or sometimes before used and Process of safe disposal of waste to landfill.

2.6. Drivers of Reverse Logistic

Reverse logistic always starts with the movement of products from the user to the producer (Arnesh 2017). Some of the companies are going for reverse logistic by recognizing the great value of it, some of them doing it because they have to and some are socially motivated to do so. The main driving force behind reverse logistics can be categorized as follows: -

1. Economic profit/Gains
2. Environmental concern
3. legislation

In the case of plastic bottles reverse logistic, a number of players are involved in the supply chain and therefore, it is important to understand, what drives users and producers to return the end-of - life or end-of-use PET bottles

2.6.1. Economic Gains

According to Lambert (2011) reviews, Economic gains contribute significantly to the recovery of products. Which refers that, the second motivation for implementing RL are economic factors. Due to this case, most product flows in today's supply chain do not ends once to it reaches to the consumers (Fleischmann 2001). This means, a product is capable of leading a second, third or even fourth life after accomplishing its initial purpose. In the case of a company, this results direct and indirect benefits (Akdogan 2012). Based on the reviews, direct and indirect gains in all recovery actions are related economic benefits. Recovery of waste products can result in a company decreasing the use of raw materials, which is a direct benefit.

As In developing economies, most reverse logistic is conducted by the informal sector. However, these informal sectors consist of six groups and together they form a waste recycling hierarchy (Wilson 2006)

2.6.2. Legislation

Legislation refers to any rule that a company should recover its products or accept to take back (Peters 2009). Based on the author reviews, in many developed economies, the concept of legislation works as the government forces companies to address the issue of proper disposal and recovering value in end- of- life products.

According to Huber, et al. (2006) reviews, policies aimed at increasing household recycling based on two economic mechanisms; financial incentive and reduction of the time and convenience costs associated with recycling. Financial incentive can be applied based on the fees, which is based on the volume of garbage that the household disposes, reduction of time and convenience costs associated with recycling are reduced by measures such as the provision of curbside recycling and availability of nearby community recycling facilities.

2.6.3. Environmental concerns.

Environmental cases, CO2 emissions due to the production of virgin polymer are 6 kg per polymer, while it is 3.5 kg for recycled plastics (Wong 2010). For companies that uphold environmental concerns, the use of recycled plastics is an advantage as it contributes to less environmental pollution. In this era of sustainability, environmental concerns have become a marketing strategy for companies and therefore it’s been used to gain consumer confidence (Coelho 2011).

2.7. Product recovery management

Management of product recovery is one part of the RL system. Products are collected after once customers are used and recovered through different mechanisms depending on different product characteristic. Based on different product recovery strategies, several literatures categorized them as: -reuse, repair, recycling, re-manufacturing refurbishment and disposal. Each activity strategy will be elaborated in detail as below (Christensen 2002).

A Recycling: this recovery strategy is to reuse the materials use products in production of the of the original parts.in this process the identity and functionality of used products and components are lots.

B. Direct reuse: -when an item or a product is directly reused after collection without any recovery activity. Some examples including packaging materials.

C. Repair: -repair recovery includes additional activities, limited dis assembly and replacing of broken parts are some of them.

D. Remanufacturing: -it is process in which bringing used products to make or produce the quality standard of new products.in this case used products will retain their identity and functionality.

F. Refurbishment: -a process in which parts of the returned products are replaced and fixed with new parts, and in which they are reassembled as refurbishment products.

2.8. Recycling plastic

According to (Edward 2009) definitions, Plastic is light, easy to store and transport, comes in an endless variety of textures and shapes, and can hold almost anything. These properties make plastic attractive to manufacturers. Plastic is in almost everything we touch. that means, everything we used is made up of plastic. It’s used to make our clothes, cars, toys, and household products. Many of the food, health, and beauty products we enjoy come in plastic packaging.

2.8.1. Types of plastics

The six most common types of plastic can easily be recycled. The plastics industry has voluntarily devised a coding system which makes recycling plastics easier. Table below shows these 6 types of plastics with their identification code, general properties and common uses.

Table 1 Types of plastics and common uses

Type of plastic	Identification code	General properties	Common uses
Polyethylene terephthalate (PET/PETE)	1 PET	➢ Clear ➢ Hard ➢ Tough ➢ Barrier to gas and water ➢ Resistance to heat ➢ Resistance to grease/oil	❖ Mineral water bottles ❖ 2-liter soda bottles ❖ Cooking oil bottles ❖ Powder detergent Jars ❖ Fiber for clothing ❖ Fiber for carpets ❖ Strapping ❖ Peanut butter jars
High density polyethylene (HDPE)	2 HDPE	➢ Barrier to water ➢ Chemical resistance ➢ Hard to semi-flexible ➢ Strong ➢ Soft waxy surface ➢ Low cost ➢ Permeable to gas ➢ Natural milky white color	❖ Jerry cans ❖ shopping bags ❖ Film ❖ Milk packaging ❖ Toys ❖ Buckets ❖ Rigid pipes ❖ Crates ❖ Bottle caps
Polyvinyl chloride (PVC)	3 PVC	➢ Transparent ➢ Hard, rigid ➢ Good chemical resistance ➢ Long term stability ➢ Electrical insulation ➢ Low gas permeability	❖ Pipes and fittings ❖ Carpet backing ❖ Window frames ❖ Water, shampoo and vegetable oil bottles ❖ Credit cards ❖ Wire and cable sheathing ❖ Floor coverings ❖ Shoe soles and uppers

Low density polyethylene (LDPE)		➢ Tough ➢ Flexible ➢ Waxy surface ➢ Soft scratches easily ➢ Good transparency ➢ Low melting point ➢ Stable electrical properties ➢ Moisture barrier	❖ Agricultural films ❖ Refuse sacks ❖ Packaging films ❖ Foams ❖ Bubble wrap ❖ Flexible bottles ❖ Wire and cable applications
Poly propylene (PP)		➢ Excellent chemical resistance ➢ High melting point ➢ Hard, but flexible ➢ Waxy surface ➢ Translucent ➢ Strong	❖ Yoghurt containers ❖ Potato crisp bags ❖ Drinking straws ❖ Medicine bottles ❖ crates, ❖ plant pots ❖ Car battery cases ❖ Heavy instrument bags
Polystyrene (PS)		➢ Clear to opaque ➢ Glassy surface ➢ Rigid ➢ Hard ➢ Brittle ➢ High clarity ➢ Affected by fats and solvents	❖ Packaging pellets ❖ Yoghurt containers ❖ Fast food trays ❖ disposable cutlery ❖ Coat hangers
Other plastics		Other (usually a mixture of resins) Food containers, including polycarbonate used in baby bottles, "sport" water bottles, New bio-based plastics may also be labeled #7.	❖ Mostly not available Insufficient quantities for recycling

(Sources: www.recoup.org)

2.8. 2. Plastic bottle recycling

PET, stands for polyethylene terephthalate it is the most common plastic being used by consumers. RPET is made from used plastic bottles which have been collected, cleaned, smashed, melted, polymerized to be reused by manufacturing polyester fibers, polyester sheets, strapping and eve n back into PET bottles (Usman 2011).

The number of polyethylene bottles (bottles for beverages made from plastic) produced is on the rise in all countries. In many countries that have water service infrastructure in place and can provide safe and high-quality tap water, there are measures and operations being implemented to reduce the use of PET bottles, and review and promote the use of tap water (Curtis and Jerry 2016).

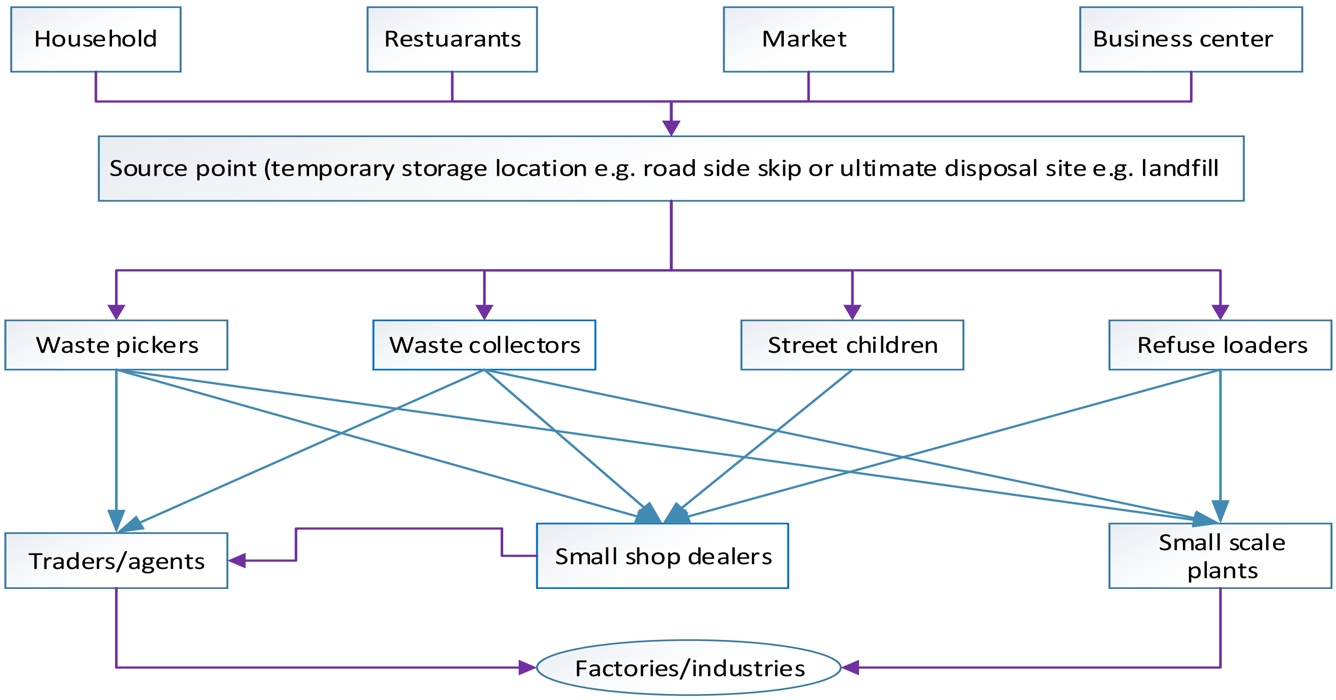


Figure 6 Plastic bottle recycling activities

Source: - IGNIS, Waste Management Hierarchy 2011

Currently, due to challenges and difficulty for recycling of PET and Plastic water bottles recycling has achieved greater policy prominence. There are two reasons for the increased focus on recycling plastic water bottles. First, the volume of waste associated with plastic water bottles is substantial and increasing, rising from time to time (Viscusi 2006). Plastics have opened the way for new inventions and have replaced other materials in existing products. They are light, durable and versatile, as well as resistant to moisture, chemicals and decay. Yet, these properties can also bring challenges to waste managers in local and regional authorities (Hannequart 2004).

2.8.3. System for plastic recycling

There are different ways of plastic material recycling based on the polymers type, package design and product type (Edward 2009). Thermoplastics, including PET, HDPE all have high potential to be mechanically recycled. Thermosetting polymers such as unsaturated polyester or epoxy resin cannot be mechanically recycled, except to be potentially re-used as filler materials once they have been size-reduced or pulverized to fine particles or powders (Rebeiz & Craft 1995). There are several steps to follow.

A. Collection

Collection of plastic wastes can be done by bring systems or through garbage collection system. Collection in the context of reverse logistics can be defined as a process by which recyclable materials are diverted from general waste stream and delivered to a processing facility (Pohlen 1992).

B. Sorting or Separation

Collected products need to be organized and sorted depending on their characteristics. For this returned product firstly inspected with respect to quality and composition order so as to determine the appropriate recovery routine. Inspection, separation and sorting stage occurs at the collection point where the products are inspected and sorted on the basis of their quality (Badenhorst 2013).

C. Product redistribution

Product Redistribution is a process in which the last activity in reverse logistics network, it refers to directing reusable or recovered product to secondary market or physically moving to them to future users, this step mainly involves transportation and storage activities in reverse logistic (Fleishmann 2000).

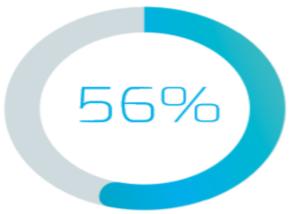
2.9. Status of Plastic Bottle Recycling

It was known that plastic is a material which is not suited for recycling because of its nature. It is different from aluminum cans and glass bottles, it is very difficult to remove dirt from plastic waste while maintaining its homogeneity and recycle it into plastic bottles (Yamashita 2003). According to a survey, the total rate of collecting plastic bottle in 2012 was 79.6% and the rate of recycling them into plastic bottle was 11.4% (Shimbu 2014).

2.9.1. Global recycling trade

According to Costas (2014) reviews, the annual volume of globally traded waste plastics is around 15 Mt, less than 5% wt. of the new plastics production in 2012. Such a small percentage suggests international trade is a minor means to extract their resource value. Europe collectively is the major exporter, with the world's top 5 country exporters being Hong Kong SAR (re-exporting imported material to China), USA, Japan, Germany and the UK. The top world importers are: China at $6.1B and its SAR Hong Kong at $1.65B, followed by the USA, the Netherlands and Belgium. Plastic scrap flows from Western countries with established collection systems mainly to China, which dominates the international market, receiving around 56%.

2.9.2.1 China's recycling trade capacity



China is the leading importing country for waste plastics China receives 56% (by weight) of the global imports of waste plastics

Based on the Costa (2014) reviews, China, including the Hong Kong SAR, is the key player in the global market for plastic waste, being by far the biggest importer (49% of financial transactions for imports - 56% wt.)

The study reviews that, there was five top exporters in the world were Hong SAR>USA>Japan>Germany>UK Europe collectively is the major exporter. An overview of the most important exporters to china is provided. some of these exporting countries or areas are considerable in more detail as figure below.

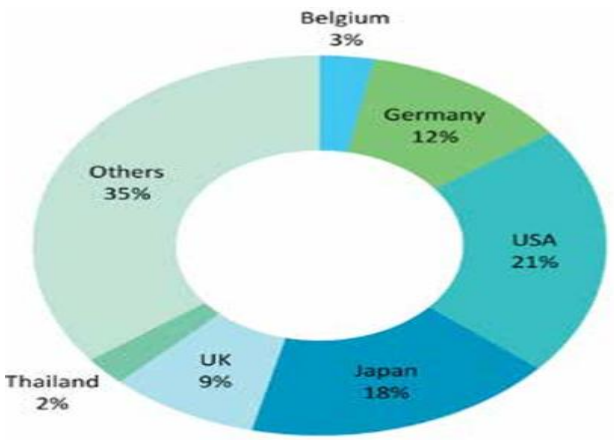


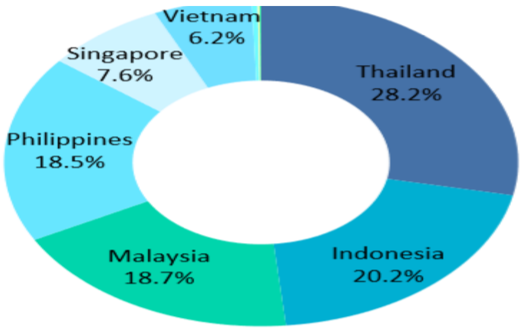
Figure 7 World exports of recovered plastics to China including HK in 2011. After Zhou2

(Data Source from UN Com-trade, 2016)

2.9.3.2. South-East Asia (ASEAN)

According to Costa (2014) reviewed, around 10 countries of the south East of Asia region (Malaysia, Singapore, Brunei, Darussalam, Thailand, Philippines, Vietnam, Myanmar, Indonesia, Cambodia and Lao PDR) are part of the Association of south Est Asia Nations

(ASEAN). as study indicates, they import around 3% wt. Of the global trade (2011 data) and export around 5% of the global trade.



ASEAN countries (mainly Vietnam, Malaysia and Indonesia) export to China, possibly re-exporting reprocessed waste imports and exporting domestically collected plastic scrap.

Source: - south east Asia trade capacity, 2011

2.9.4.3 USA recycling trade capacity

As study indicates that, USA is the largest waste plastics supplier to china. It is the second largest consumer of plastics in the world and depends mainly to china and HK for absorbing its waste plastics Neigh-boring countries. such as Canada and Mexico are also a small market outlet According to institute of scrap recycling industries (ISRI 2012). USA exported 2.1Mt of plastic waste, worth $1.05 Billion. Most of the value of the transactions was with China and the Hong Kong SAR ($ 547 million and $ 240 million respectively). Currently, China has a potential and experience for recycling plastic solid waste in today's market (Shimbu 2014).

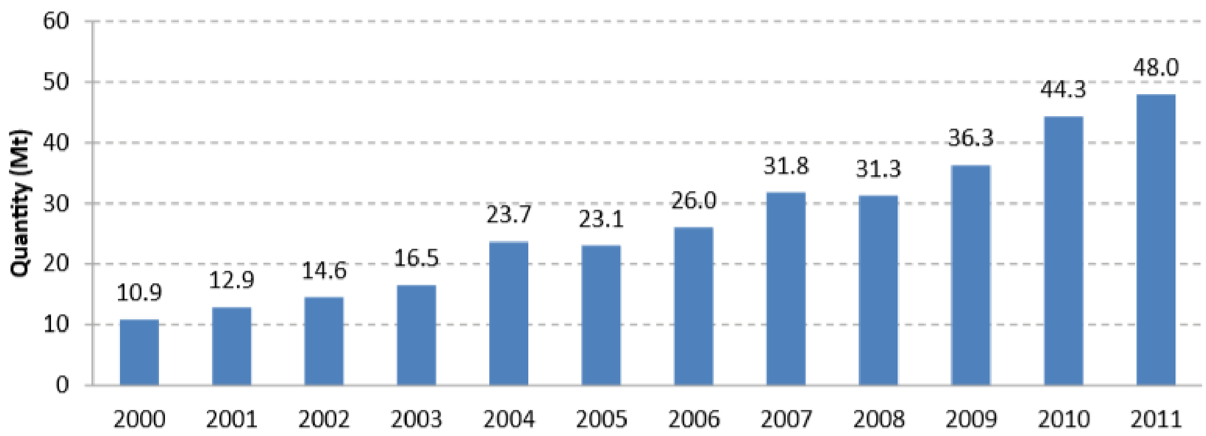


Figure 8 Demand for primary plastics in China. Data source:

(China Statistical Database28. After Zhou2)

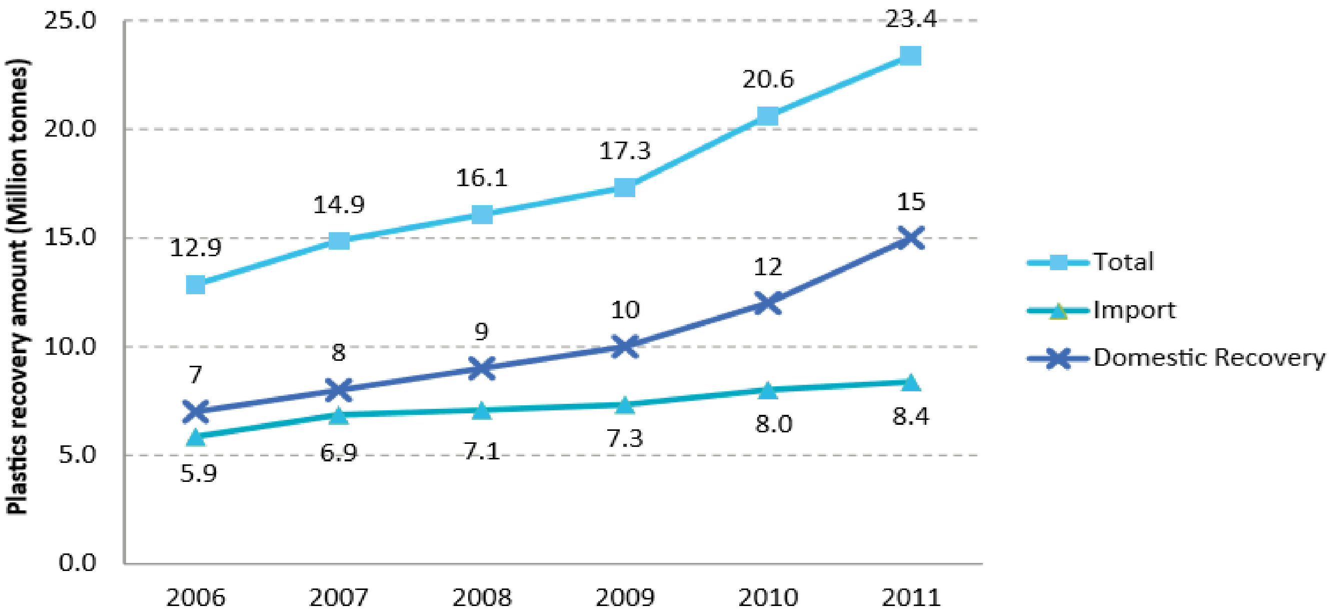


Figure 9 Total plastics recovery in China

(Import data source: China Customs Statistics (CCS) 27)

Above figure shows that, states of recovery of plastic bottles and primary demand solid plastic recovery in China. According to Moore (2012)reviewed, imported waste PET comes mainly from the USA, Germany, Japan, Thailand, Mexico, Korea and Taiwan, and recycling facilities are concentrated in eastern China, especially Zhejiang and Jungian (Hang, 2012).

According to Costa (2014) reviewed, based on the Assumption 2, The weighted average for a PET container is **38.725** grams/unit. This is based on weight-to-unit conversion data from the Manitoba Product Stewardship Corporation (MPSC) representing all PET beverage containers, which is based on a mix of units of various sizes.

2.10. Economic benefits of plastic bottle recovery

As simple observation Recycling is not only makes environmental sense, but also economic sense. On a national scale, recycling has encouraged the growth of an industry and created jobs. Of course, there are same costs associated with recycling, as there are with all other day –to-day operations over seen by other companies and organizations.

According to Bernon eta al. (2011) reverse logistics process is managed correctly and can be minimize logistics costs and improve revenue. Hence effective reverse logistics management can add significantly to an organization's profitability (Mollenkopf 2005). It adequate resources (tangible/intangible or property-based/ knowledge-based) are targeted to reverse logistics program, this can have tremendous positive financial impact (Genchev 2010).

2.11. Reverse Logistic Network Design Model

Basically, RLND is normally documented as a strategic supply chain issue of major importance. The location of production facilities, storage concepts, and transportation strategies are major determinants of supply chain performance (Moritz 2001).Design of product recovery network is one of the important and challenging problems in the field of reverse logistics (Zhongfeng 2009). The design and management of a reverse logistics network is more complex than that of forward logistics networks with direct flows (Yimsiri 2009).The main two factors two factors that cause these difficulties are:

- The simultaneous existence and mutual impact of the two types of flow: the possible coordination / integration and interfering constraints between forward and reverse flows must be considered.
- The existence of numerous uncertainties about the return flows such as choice of recovery options, quality of return objects, quantity and reprocessing time (Jayaraman, et al. 2003).

According to Ronald et al. (2000) states, product recovery is acquiring more attention recently due to sustainability and growing of environmental concerns. Therefore, due to all this fact, efficient implementation requires appropriate reverse logistic structures to be set up for the arising goods from users to producers.

According to Ene and Ozturk (2014) reverse logistic network can be visualized indifferent perspective. Based on (Fleischmann 2000) reviews, based on the characteristics of product recovery networks by dividing them into three types (bulk recycling, assembly product re-manufacturing, and re-usable items) and then classifying network characteristics within each type (e.g. dedicated facilities, reuse in original market, mandatory recovery). So, network types depending on the disposition types of products.

According to Beullens and Dekker (2004) and categorized the network types depending on the disposition types, namely re-manufacturing, recycling, and direct reuse networks.

Based on Fleischmann, et al. (1997) Reverse logistics systems can be classified into four major categories considering types of return items. These four classes are directly reusable network (DRN), re-manufacturing network (RMN), and repair service network (RSN) and recycling network (RN). Each network has their own characteristic as described below:

A. **Direct reuse networks (DRN):** it is design for items like pallets, container. Nothing to be done here. Just it is collect and send to the market directly for cleaning and minor maintenance if needed.it is a closed loop supply chain due to the interrelation of the forward and reverse flow.
B. **Re-manufacturing networks (RMN):** which is similar with discussed above and it is also a closed-loop network. Since the re-manufacturing process implemented by original producer.
C. **Recycling Networks (RN):** this process is different from the above discussed network types. Its characteristics is an open-loop network due to the operation is carried by third party specialized in the recycling process.
D. **Repair service network (RSN):** defective products, such as durable goods or electronics equipment, are returned and repaired in service centers. There are few links between forward logistic and reverse logistic, so it is considered an opened-loop system.

2.12. Barriers that affecting implementation of Reverse Logistic Network Design Model

In spite of practice related to reverse logistics activities that cause of environment protection, which practices related to any activity is not free from barriers (Lembke 1998).

2.12.1. Lack of information and technological system

According to Lembrk (1998) reviews, the most problem faced in the implementation of reverse logistic today is the death of good information system. An efficient information system is very necessary for supporting the reverse logistics during various stages of the product life cycle. Clear information and technological system can be actual useful for the product development programs.

Based on the review of Flapper (2002) efficient information systems are needed for individually tracking and tracing the returns on the product, linking with the previous sales. Relating the product return with a past sale can support forecasting of product returns, thus helping in the inventory management system to control the bullwhip effect of the inventory.

2.12.2. Lack of awareness about reverse logistics

According to review of Hock (1999) reviews, lack of awareness about implementation of reverse logistic affect environmental and economic aspect. Awareness creation is valued when given to strength for sustainability, through the whole supply chain networks. It is most valued when awareness is given through the whole supply chain network.

2.12.3. Financial constraints

Based on the review of Rogers et al. (1998) reviews, reverse logistic system is mostly affected due luck of enough financial to run and support the system. Since, all activities in line of the system is carried out through financial issues. Even information flow from upper steam to down steam in reverse logistic system require more funds because without these, the returns product tracking, tracing and product recovery by various process like reuse, recycling, re-manufacturing etc.is all not possible without financial issues.

2.12.4. Problem with product quality

Another important barriers affecting reverse logistics is the condition of the quality of the end of life returned products. According to Lembke (2002) reviews, in line of the reverse logistic system the product quality is not Constancy when compared with forward logistic. But expectation of the customer is the same in each levels of reverse logistic system.

2.12.5. Company policies

Company policy is so easy that, it is possible to manage when comparing to other barriers. It was created due to lack of the knowing about importance of the reverse logistics and the management in attention are related to the policies followed by the companies. According to review of Lindhovist (2000) many companies have started to integrate the recovery options for the products into their supply chain. Every companies need a brand image from his customers. They can compromise on the original products rather than returned one.

2.12.6. Resistance to change reverse logistic

According to Sydney (2001) reviews that in nature reverse logistic system is not snap shut process. It requires a radical change in the mindset and practice. Resistance to change can also be used especially in the case for small business with limited purchasing power to influence contracts with suppliers. Due to nonappearance of clear awareness about reverse logistic, some problems would be accelerating easily.

2.12.7. Lack of top management commitment

Top management commitment is a leading barrier for the successful of RL activities in every companies and organization. Review of Mintzberg (1973) states that top management commitment is the leading driver of trade activities. As simply observing our environments the most challenges for implementation of RL is less commitment of top management on this area.

2.12.8. Lack of strategic planning

According to Singh et al. (2003) reviews, reverse logistic system would be need a well strategic planning in order improve the problems in dependability. Strategic planning is the identification of reverse logistics goals and the specification of long term plans for managing them.

2.12.9. Lack of appropriate performance metrics

According to (Eltayeb 2013) reviews that performance matrix is the base for implementing reverse logistic system in order to working in line together. Lack of having appropriate performance metrics is one of the major barriers in RL system. Successful reverse logistics programs will successfully organize all the activities and processes in order to recapturing value of products through working in together. cooperativeness is the primary ideas to sustain or achieve good reverse logistic systems.

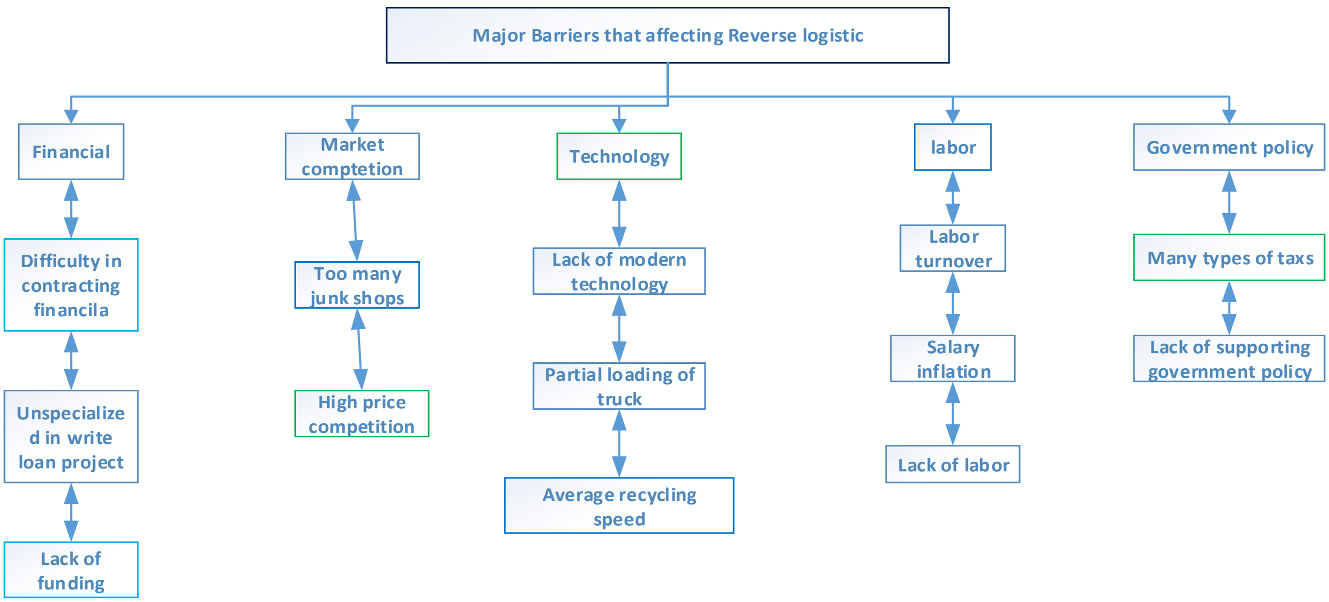
2.12.10. Reluctance of the support of dealers, distributors and retailers

Another important barrier to the RL is the reactance of the support of the dealers, distributes and retailers towards the RL activities. Based on the review of the Rogers (1998) the overflowing process for return policy can lead to the consumers returning back the product to retailers.

2.12.11. Lack of training and education

According to Rogers et al. (1998) reviews, lack of training and education is the most barriers that affect the implementation of reverse logistic in each stage. to achieve good RL, training is necessary from upper stream to downstream any companies, communities and organizations. training and education is a major challenge to commercial recycling (Mintzberg 2001).

Summary of major barriers that affecting reverses logistic



Source: - Barriers affecting Sustainability of reverse logistic, 2015

Figure 10 Barriers that affecting mostly reverses logistic in any organization and companies.

Using systematic literature review all above mentioned, different variables or Barriers that affecting mostly the implementation of RL any company's and organization are identified.

2.13. Tools used for analyzing Barriers in Reverse Logistic system

Lastly, the outcome of this all identified Barriers, was analysis through ISM to identify the driver power of the variables, dependent, independent relationship of the variables and linkage variable and interrelationships between them. The detailed description of ISM is illustrated in the following subsections

1.Interpretive Structural Modeling: - Interpretive Structural Modeling was first proposed by J. War-field in 1973 to analyze the complex socioeconomic systems. ISM is a computer-assisted learning process that enables individuals or groups to develop a map of the complex relationships between the many elements involved in a complex situation. ISM is often used to provide fundamental understanding of complex situations, as well as to put together a course of action for solving a problem (Warfield, et al. 1979).

2. Analytical Hierarchy process (AHP)

According to Brunelli (2015) define AHP as a theory and methodology for relative measurement. In relative measurement we are not interested in the exact measurement of some quantities, but rather on the proportions between them. Relative measurement theory suits particularly well problems where the best alternative has to be chosen (Zhu 2014).

3. **analytic network process** (**ANP**) is a more general form of the analytic hierarchy process (AHP) used in multi-criteria decision analysis. AHP structures a decision problem into a hierarchy with a goal, decision criteria, and alternatives, while the ANP structures it as a network.

Table 2 Figure 12 Brief comparison between AHP, ANP and ISM

S.no	Analytic Hierarchy process (AHP)	Analytic Network Process (ANP)	Interpretive Structural Modelling Technique (ISM)
1	Discipline of hierarchy has to be strictly followed	Deals with loose networks	Involves a set of interconnected criteria
2	Assumes functional independence of an upper part of hierarchy from its lower one	Takes into account the Interdependence and non-linearity	Establishes the “leads to” relationships among the criteria
3	Fails in complex real-life problems	Useful in real life non-linear Problems	Captures the complexities of real life problems
4	Moderate ability for capturing dynamic complexity	Lower ability for capturing Complexity	Higher ability for capturing dynamic complexity

(Source: Jitesh Thakkar 2008)

Table 3 Summary of literature on revers logistic network design model.

No.	authors	Title	Objective	Tools	Optimization tool(software)	Finding	Country
1	Xiaoyun	Sustainable reverse logistics network design for household plastic waste	Provide decision support on choosing the most suitable combination of separation methods	mixed integer linear programming (MILP) model	IBM Logic Net Plus 7.1	Minimizes both transportation cost and environmental impact.	Netherlands.
2	Khajavi	RLN Optimization Model for Multistage Capacities Supply Chain	To minimize the total costs and maximize the responsiveness of the closed-loop supply chain network simultaneously.	mixed-integer programming model (MIP)	branch and bound algorithm	Avoid sub-optimality caused by separate design of the forward and reverse logistics networks.	Iran
3	Jayant et al…	Design and Simulation of RLN	modeling and simulation of RLND for collection of EOL products	Simulation modeling	Arena 11.0 simulation package	Model calculates cycle time, transfer time, transfer cost, and resource utilization	North India
5	Vlachos	Decision Making In RL Using System Dynamics	To introduce a new approach on the study of reverse logistics.	System Dynamics (SD)	Decision making	Illustrative how SD modeling can be used to produce a powerful long-term decision-making tool.	Greece
6	Yang	Hierarchical Facility Location for the RLND under Uncertainty	to locate interacting facilities in an efficient and cost attractive manner	Hierarchical Facility Location	uncertain cost minimization model is used	Optimal locations for the RLN with different flow patterns are compared	China
7	Saman	RLND using simulated annealing	to minimize the transportation and fixed opening costs in a multistage RLN	mixed integer linear programming model	simulated annealing (SA) algorithm	to find the near optimal Solution.	London

Table 4 Summary of papers reviewed

No.	Papers reviewed /journals reviewed	Number of papers reviewed
1	Journal of Multidisciplinary Engineering Science and Technology	**2**
2	European Journal of Operational Research	**3**
3	Institute for Global Environmental Strategies (IGES)	**4**
4	Journal of Environmental Science and Engineering	**3**
5	Int. Journal of Business Science and Applied Management	**5**
6	International Journal of Physical Distribution and Materials Management	**7**
7	International Journal of Waste Resources	**8**
8	Journal of Business logistics	**9**
9	International Journal of Advanced Manufacturing Technology	**8**
10	International Journal of Environmental Protection and Policy	**11**
11	International Journal of Logistics Management	**12**

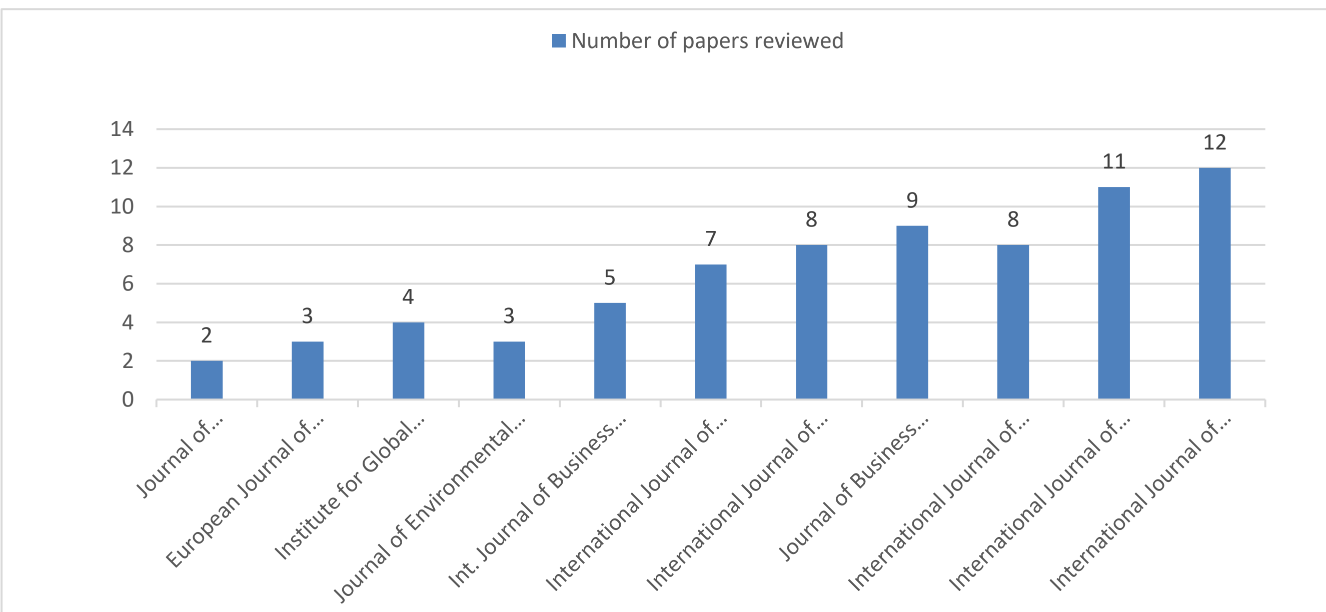


Figure 11 summary of the number of papers reviewed

Table 5 literature summary, issues critically examined in the literature

No	Authors	year	Objective	Methodology	Findings/contribution
1	Vaidy Jayaraman	2001	Design of Reverse Distribution Networks: Models and Solution Procedures	Heuristic concentration procedure	"Heuristic expansion" was also performed using the solution found with a greedy Heuristic to provide a short-list of potential facility sites.
2	Vlachos	2003	To introduce a new approach on the study of reverse logistics.	System Dynamics (SD	Shows how SD modeling can be used to produce a powerful long-term decision-making tool.
3	Pumpinyo	2014	To focus the investigation on the current practices in the RL systems.	qualitative and quantitative methods was employed	Analysis shows waste managed by a cooperative-like franchise of SCs perceived that their practices were more efficient than non-franchise practices.
4	Viscusiy and Jason Bell	2006	To increasing household recycling	Empirical Hypothesis	Economic mechanisms: Financial incentives and reduction of the time and convenience costs associated with recycling.
5	BetelhemG uta	2016	Determine the relationship between RL practice and organizational performance.	descriptive and inferential analysis is used	Based on correlation analysis RL have strong positive r/s with financial performance, market performance and organization performance.
6	Fitsum Getachew	2016	To design and analyze RLNM for recyclable materials that can assign the optimal location and determine shipping volume to minimize the system operating costs.	Gravitational location and optimization model was formulated for the RLN. The model was solved with LINGO 14 software.	Through Minimization of fixed and transportation cost, he can try to propose the maximization of the collection and recycling facilities, location-allocation of recyclable materials, all of which have a great implication on strategic decision making of RLND.
7	Benjamin Ghansah and Komla Mahunu2	2015	To Providing the status of PET bottles waste in selected cities in Ghana.	Discuss critical issues relating to a potential establishment of a PET recycling firm in Ghana.	Addressing its impact or mitigating its effects.
8	Georgiadis	2004	Introduce a new approach on the study of reverse logistics.	System Dynamics (SD)	Illustrative how SD modeling can be used to produce a powerful long-term decision-making

					tool.
9	CheruMeaz a	2016	Studying the solid waste management system in Addis Ababa to find the main causes for the insufficient service delivery.	This thesis focused on finding the cause of the problem by investigating the development measures the city took.	Three methods have been suggested; 1. importing the appropriate waste. 2.environmental management education 3.for-formalizing the informal waste recovery system and lastly, establishing public-private partner-ship in all the waste management segments
10	Kaebernick q and Jessica Hanafi	2008	To find an effective collection strategy which considers cost and environmental impact simultaneously	Integrated collection strategy which combines a Fuzzy Colored Petri Net forecasting method and collection network model to collect EOL products.	Providing demographic data and historical sales of a relevant product in a certain location, the best strategy to collect EOL products in that location can be determined
11	Masakazu	2014	status of recycling plastic bottles in Japan and recycling methods, and examines whether or not they are effective in terms of reducing energy consumption	Comparison of Energy Consumption Required for Different Recycling Methods	Recycling of plastic bottles is a waste of energy. It is better to combust used plastic bottles, rather than recycle them, to produce and utilize heat.
12	Bupe Mwanza and Charles Mbohwa	2017	Recycling and RL in order to determine the significance of sustainable resource utilization and waste management.	Used Scenario study approach	merits in implementing reverse logistics systems and these can benefit the developing economies
13	Joao Menezes	2009	The elements of customer service and their importance in RL for recycling.	Applying multivariate statistical methods	Suggest important guidelines to improve such a complex logistics service.

Research summary and Gap

This are some of the points that can be try to summarizes the gaps that observed from the literature and related to the research study areas.

- In previous literature, most of the reverse logistics network design models have only one objective minimizing total costs. However, environmental impact is becoming increasingly important and economic advantages from the reverse logistic are the most important especially for thus developing countries such as Ethiopia.
- But some research tries to recommend that, Recycling is well-known for its environmental benefits, which include resource conservation, energy conservation and reductions in water and air pollution, including reductions in greenhouse gas generation, as many researchers are often overlooked.
- Mostly in the area of plastic bottle reverse logistics, European countries such as Germany, Turkey, Holland, Greece and other Asian Country's such as China, Indian, and USA are the leading contributors in the area. However, the analysis of the real case studies in RL from African countries including our countries have not been still impressed on this area (Solvang et al, 2016).
- According to institute of scrap recycling industries (ISRI 2012) USA exported 2.1Mt of plastic waste, worth $1.05 Billion. Most of the value of the transactions was with China and the Hong Kong SAR ($ 547 million and $ 240 million respectively). this shows that, there was no one country's can participate from Africa.so we lose a lot advantage from it. This case due to lack of top management commitment and lack of awareness created on advantage achieved from recovering of solid plastic waste.

Therefore, the study identified no more studies on plastic bottle reverse logistics and plastic recycling in Africa and therefore recommended that more research is needed on this topic and it was serious issues for environmental aspects and becoming economic advantageous through recycling of plastic bottles.

CHAPTER THREE

3. Research Methodology

This chapter presents the research design and methodology used in the study. It describes in detail the general intention of the research and the methods used for data collection and analysis. It includes a highlight about the study area, research design; methods of data collection and data analysis methods and the last illustrates the data analysis method and tools used to optimizing the model.

3.1. Study area

Dire Dawa city administration is a large town in Ethiopia with a diverse ethnic and cultural population. It is situated along the Addis Ababa to Djibouti pathway, an asphalt road and railway that links the country to neighboring Djibouti. Dire Dawa has several economic and social institutions with a large number of permanent and temporary employees, including the Djibouti railway station, textile, food factories, some cement factory and higher-education institutions with a large number of students. There also are many hotels and bars in the town. Even Industry Park is also the way to constructing a day.

In Ethiopia, next to Addis Ababa and Hawassa, Dire Dawa is the highest west generators with 0.34 kg/capital/day waste generation rate. However, only 65% of the generated waste is collected (Tesema 2014). The remaining amount of waste is illegally disposed on unauthorized place such as in drainage lines, open spaces, street sides (Semere 2014). The other technical element of solid waste management such as sorting, transfer and transportation, treatment and disposal hold a lesser attention from the city municipality. The study of Hailu (2013) confirmed that the distribution of communal container is inequitable, the containers are not periodically picked and emptied, land filled managed poorly, recycling is neglected, and the participation of stakeholders is insignificant (Hailu, 2013).

Therefore, this research is more based in Dire Dawa city. Since Dire Dawa was more advantages through transportation system currently, as it has railway line from Addis Ababa to Djibouti.

Pair-Wise Comparison for Selecting Study Area using AHP method

Factors used for comparison.

- transportation
- weather condition based on the environment temperature
- water quality based on the salt contents
- based on the number of water bottling company
- population size
- Topography

Alternative study Area

- ✓ Mekele city
- ✓ Dire Dawa city
- ✓ Bahir Dar city
- ✓ Hawassa city

No.	Relative scale	Judgment value
1	Low	1
2	Medium	3
3	High	5
4	Extremely high	7

Number of comparison has been found using the following formula

No. of comparison $=\frac{n(n-1)}{2}$ whereas "n" stands for number of variables or things that has been used for comparison.

Therefore, number of comparison is $= \frac{4(4-1)}{2}$

4×3/2 = 6 which is number of comparison

suppose we have 4 by 4 reciprocal matrix from paired comparison

Z=

	Mek.	DD.	BD	HAW.
MEK.	1	3	5	3
DD	1/3	1	3	5
BD	1/5	1/3	1	7
HAW	1/3	1/5	1/7	1

We sum each column of the reciprocal matrix to get

Z=

	Mek.	DD.	BD	HAW.
MEK.	1	3	5	3
DD	1/3	1	3	5
BD	1/5	1/3	1	7
HAW	1/3	1/5	1/7	1
28/15	**68/15**	**64/7**	**16**	

Then we divide each element of the matrix with the sum of its column, we have normalized relative weight. The sum of each column is 1.

Z =

	Mek.	DD.	BD	HAW.	
MEK.	15/28	45/68	35/64	3/16	
DD	5/28	15/68	21/64	5/16	
BD	3/28	5/68	7/68	7/16	
HAW	5/28	3/68	1/64	1/16	
1	**1**	**1**	**1**		1

The normalized principal Eigen vector can be obtained by averaging across the rows as follows: -

$$
Z = \begin{pmatrix} & Mek. & DD. & BD & HAW. \\ DD. & 15/28 + & 45/68 + & 35/64 + & 3/16 \\ Mek. & 5/28 + & 15/68 + & 21/64 + & 5/16 \\ BD & 3/28 + & 5/68 + & 7/68 + & 7/16 \\ HAW & 5/28 + & 3/68 + & 1/64 + & 1/16 \end{pmatrix} = \begin{pmatrix} 0.4829 \\ 0.2599 \\ 0.1803 \\ 0.0752 \end{pmatrix}
$$

The normalized principal Eigen vector is also called priority vector. Since it is normalized, the sum of all elements in priority vector is 1. The priority vector shows relative weights among the variables or things that we compare. In this case, Dire Dawa**48.29**%, Mekele is **25.99**%, Bahir Dar is **18.03**%, and Hawassa is **7.52**|%

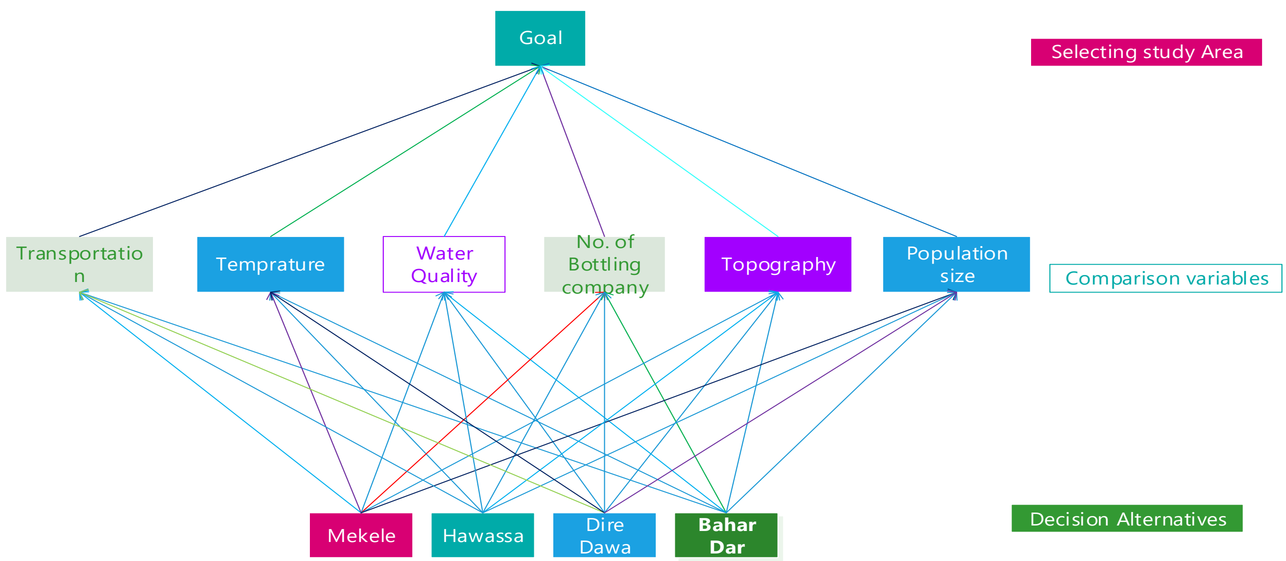


Figure 12 Analytic hierarchy process (AHP) used for selecting study area

Therefore, the most preferable decision Area is Dire Dawa City, followed by Mekele and Bahir Dar. In this case, we know more than their ranking. In fact, the relative weight is a ratio scale that we can divide among them. which means, we can say that Dire Dawa city is the most preferable decision Area, since Dire Dawa 1.86 (=48.29/25.99) times more than Mekele city, 2.68= (48.29/18.03) Bahir Dar and also Dire Dawa 6.42 (=48.29/7.52) times more than Hawassa city. Aside from the relative weight, we can also check the consistency of decision area. To do that, we need what is called Principal Eigen value. Principal Eigen value is obtained from the summation of products between each element of Eigen vector and the sum of columns of the reciprocal matrix.

3.2. Research Design

The study would be conducted in Dire Dawa city based on plastic bottle reverse logistic network design at Dire Dawa City level. Descriptive study design will be used in this study. The practice of separation plastic bottle from solid waste at home level and interpreted at the present situation based on the response of the respondents. Both qualitative and quantitative data would be used in developing this study.to develop the study case, the research try to see some practice in other countries through reviewed some literature, try to take some other areas practices like, Copa impact plastic recycling company from Addis Ababa city.

For the successful achievement of the general objectives and specific objectives of the research, the following research methodology has been used.

3.3. Methods of Data Analysis

Hence this research will use quantitative and qualitative data type, the researcher will use data analysis method which will help to analyze both types of data. For the quantitative types of data due to the fact that large number of respondents will address through close ended question is used. In the case of qualitative research, the researcher will use content analysis, involving descriptions of the study and this helps to go beyond conceptions and generate and revise frameworks.

3.5 method of data collection

Primary data will be collected through questioner, interview, and observation etc. (Kothari C.R 2004). In order to collect relevant data for the study the following data collection techniques will be employed.

3.5.1. Questionnaires

Questioner is quite popular in the case of big inquiry (Kothari, CR 2004).The questionnaire has consisted of questions both open and closed in which if answered well, were exhausted the research question and objectives. As a result, the study should address selected bottling company and medium and small-scale enterprises in the city. So, to address the sample of this group, questioner is appropriate to take representative and reliable data.

3.5.2. Interview

This data collection technique helps to get detail information from the respondents. The respondents of the interview were experts and higher officials of sanitation and beautification agency, environmental protection authority, Health bureau, kebele officials, and association's companies' employee and managers. This type of interview helps to compare and contrast the information obtained from different respondent, and to add some other relevant points at the time of the interview.

3.5.3. Observation

Observations were carried out by the researcher to get firsthand information by directly observing wastes in bottling companies, sanitary land filled site which is situated outside the boundary of the city administration, transfer stations, transportation, illegal dumping sites, storage practice and the activity of street sweeping.

3.5.4. Document analysis

The analysis documents that obtained from the companies, administration, sanitation and beautification agency and etc. Secondary documents were analyzed and interpreted to provide a base line data with which the collected primary data results can be compared, to get back ground information and generally to enrich the research paper with second hand data.

3.6. Sampling Design

3.6.1. The target population

The target population of this study will be Dire Dawa city administration, Dire Dawa city sanitation and beautification agency, Dire Dawa city water bottling company and Dire Dawa city medium and small enterprises. Because the finding of this study is going to infer or generalize plastic bottle waste management practice in Dire Dawa city administration.

3.6.2. Sampling units

Hence this study is about plastic bottle waste management practice in the city; the study will include units that have a direct and indirect contribution for the effectiveness and/or in adequateness of the municipal solid waste management service. Therefore, the study will have the following sampling unit; bottling companies, universities, schools, Households, commercial centers, hotels, hospitals, collection service provider associations, and stakeholders.

3.6.3. Sample Frame

The sampling frame constitutes the list of units in Dire Dawa city administration. According to the study which conducted by (Hailu 2014) the number of households for the current year (2008 E.C.) are estimated 65,621 (sixty-five thousand six hundred twenty-one), five government and private hospitals, 11 solid waste collection service provider, one local NGO which works on waste management, three commercial centers, and 75 hotels are found.

3.6. Tools to be used in the Research

ISM is a computer-assisted learning process that enables individuals or groups to develop a map of the complex relationships between many elements involved in a complex situation. Its basic idea is to use experts' practical experience and knowledge to decompose a complicated system into several sub-systems and construct a multilevel structural model. ISM is often used to provide fundamental understanding of complex situations, as well as to put together a course of action for solving a problem using **MICMAC** software.

The truck rout optimization model for collection of plastic bottle from temporary storage was formulated for the reverse logistics network; the model was solved for case truck rout for collection center with **LINGO 17** software package as non-linear and mixed integer linear programming problem respectively. Lingo is simple and flexible tool for utilizing the power of linear and non-linear optimization to formulate problems concisely. LINGO 17 contains a set of built-in solvers Reverse Logistics Network Design and Analysis for plastic bottles.

Lastly performance of proposed network for collection of plastic bottles was checked using with **Arena 14.50.00002** software. Arena Simulation package by Rockwell, which allows such modular design that has been used to create the simulation model.

3.6.1 Reverse Logistics Network Model Formulation

The method of reverse logistic network model formulation, was intends to present or illustrate a transportation model formulation with respect to capacity of the truck rout and demand of the temporary storage that can be assigned in the Dire Dawa city based on information obtained from **googleearth-win-pro-7.3.0.3832.exe**. the truck rout has been based on the number of collection centers assigned. For this case there are around 12 destination that have been assign for collection center. That means that, one truck can arrive around four destinations.so, the cost of all three-truck rout can be analysis using **LINGO 17.0 software.** For those Three truck routs, models are presented, that used to minimize the total cost of transportation routes when collecting of plastic bottles from all destination in using reverse logistics system design in the city. The assumptions considered for the models are also briefly stated below together with the variables and parameters.

To / From	TS_1	TS_2	$TS_3 \ldots TS_n$	Supply
CC_1	C_1	C_2	C_3**…. Cn**	
CC_2	C_1	C_2	C_3**……**C_n	
.	.	.	.	
.	.	.	.	
.	.	.	.	
CC_N	**C_N**	**C_N**	**C_N**	
Demand				

In transportation problem, the goal is to give service or produce product at supply location or origins in transport them into destination where at demand is at minimum cost.

We would write and linear programming (LP) formulation for this transportation matrix.

Where: -TS…………………stands for temporary storage of plastic bottles.

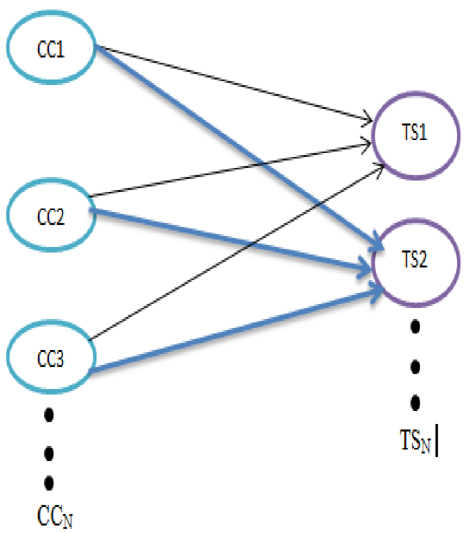
CC……………………Collection center for plastic bottles.

C ………………………cost of destination between shipments.

Let us draw a transportation network for the above matrix. The arrows from the collection center to temporary storage are called an arc and which shows the shipping cost from the collection center to temporary storage of plastic bottling.

Know let as define the decision variable for the linear programming problem (LP).

<u>Decision variables</u>



Let X_{CC1} = # of unit shipped from CC1 to TS1

X_{CC2}= # of unit shipped from CC1 to TS2

Y_{CC1} = # of unit shipped from CC2tom TS1

Y_{CC2} = # of unit shipped from CC2 to TS2

Z_{CC1} = # of unit shipped from CC3 to TS1

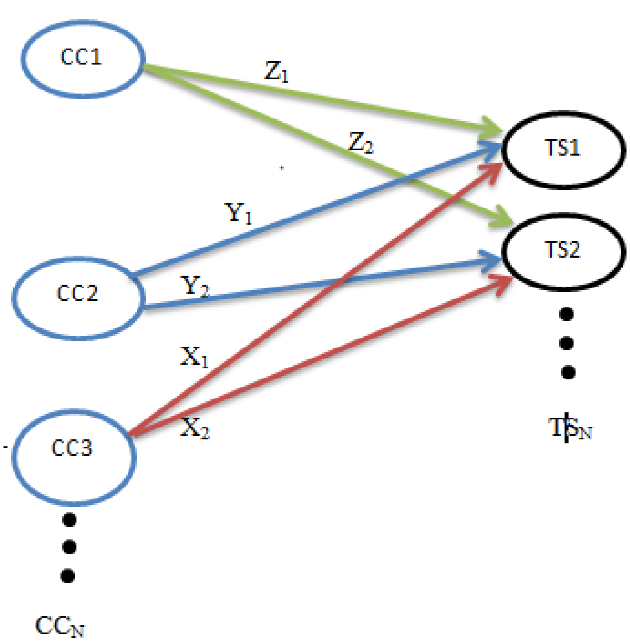
Z_{CC2} = # of unit shipped from CC3 to TS2

Let Xi j or Yij or Zij = number of unit shipped from location "i "to destination "j "

Where i=collection center 1, 2, 3... n

J= temporary storage (destination point)

Objective function is to minimizing the transportation cost among the destination. Based on this transportation network we write objective function as follows:



Objective function; min $Z_1CC1+ Z_2CC1+ Y_1CC2+ Y_2CC2+ X_1CC3+ X_2CC3 \ldots\ldots CC_N$

Subject To

$Z1_{CC1} + Y1_{CC2} + X1_{CC3} \leq$ supply of (TS1)

$Z2_{CC1} + Y2_{CC2} + X2_{CC3} \leq$ supply of TS2

$XCC_1+YCC_1+ZCC_1+\ldots CC_N$=demand of TS1

$XCC_2+YCC_2+ZCC_2+\ldots CC_N=DD$ OF TS2

$XCC_N+YCC_N+ZCC_N=$ DD of TS_n

Where X_{cc1}, Ycc_1, Zcc_1, Xcc_2, Ycc_2, Zcc_2, Xcc_3, Ycc_3, $Zcc_3 \geq 0$ Or $X_{i\,j,} \geq 0$

Developing the above assumption into mathematical model.

Model Assumption

Plastic bottle collection Reverse logistic network assumption model has been formulated through taking consideration the following expectations:

A. Collection center for plastic bottle in the city is known. based on the information obtained from the data and observation.

B. The amount of plastic bottle generated in the city is taken as assumption based on the consumption of Dire Dawa city community.

C. A temporary storage for waste management, after collection from door to door is assigned.

D. Distance and Time spent by truck between the destination is known Using from **googleearth-win-pro-7.3.0.3832.**

E. IV. The collected recyclable material contains impurities, the material for reprocessing must be classified at the centralized collection center then transported to the recycling plant according to some proportion.

F. Other miscellaneous fixed costs and variable costs regarding to plastic bottle reverse logistic system in the city is estimated.

Variables and parameters

The parameters and the variable used in the model formulation for this study is listed as follows:

A. <u>variable's</u>

I, ……. index for initial collection points.

J……. index for centralize collection centers

-K……. index for centralized collection center.

Cc, …. collection center

Di, ……. destination for collection point

Ts, temporary storage of plastic bottles.

D……. destination

Capacity

n, …… number of allocation for collection center

M……. number of market or demand point

Fj, ……...fixed cost

Vj……...variable cost

Ci, …...Shipping cost for one destination to the next destination

D……...demand from the market

Model formulation

$$\text{Min } Z = \sum_{i=1}^{n} Ts + Ci + \sum_{j=1}^{dn} fj + Vj$$

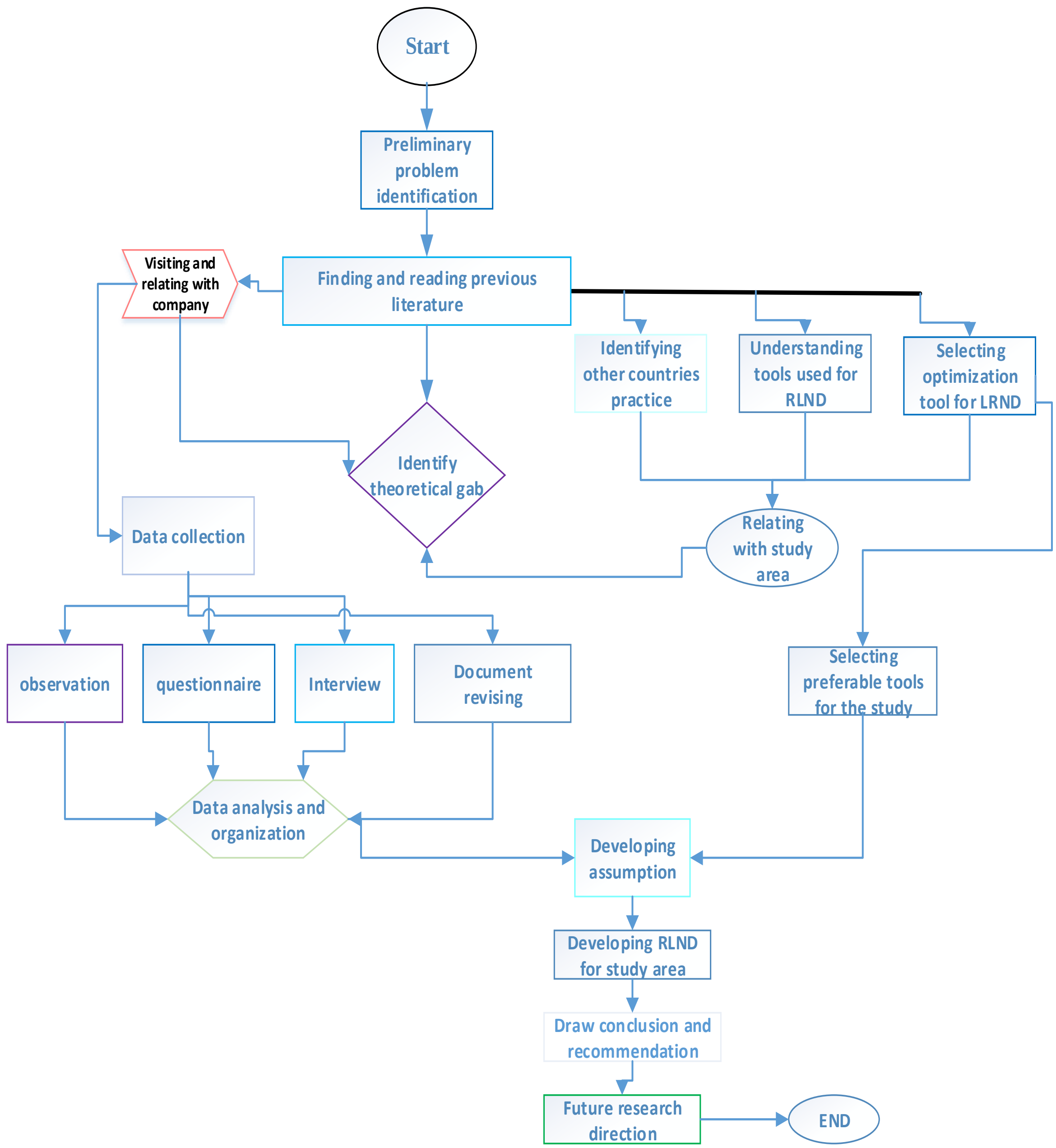
$$\text{Subject to } \sum_{i=}^{13} x^{i} = D \quad \text{for } i = 13$$

$$\sum_{J=1} Xij = Ki, yi \quad \text{for } j = n$$

$$Y \in [0, 1] \quad \text{for } i = 1 \ldots n,\ X\,i\,j \geq 0$$

3.7. Summaries of Research methodology

Based in the study and works of other experts and searching some literatures, will be observed that for plastic bottle recycling reverse logistic, different steps and procedures will be carried out, which have been shown in figure below



Source: - own

Figure 13 Research flow diagram.

CHAPTER 4

Result and Discussion

4.1. Reverse Logistic Network Model Assumption

This chapter deals more about barriers that hinders the application of reverse logistic in Dire Dawa city using the ISM methodology, which shows the interrelationships of the barriers and their levels. These barriers are also categorized depending on their driving power and dependence. After reviewing of literature on reverse logistics and the opinion of some experts, from bottling company, Dire Dawa city Administration and Dire Dawa sanitation, 13 important barriers of reverse logistics have been identified. This is later used in the development of an ISM model, which is followed by the discussion of ISM methodology and **MICMAC** analysis of the developed **ISM** model.

4.2. Model development using ISM methodology

The ISM model and MICMAC analysis is adopted for decision- making through identifying the most common barriers that are affecting the application of reverse logistic in Dire Dawa city today.

4.2.1 ISM Methodology

ISM is a computer assisted learning process that enables individuals or groups to develop a map of complex relationships between map elements involved in a complex situation (Sage et al. 1977). It helps to identify direct/ indirect influential and dependence between the variables. of According to Mandal (1994)reviews, ISM methodology is used to analyze some of the important vendor selection criteria and have shown the inter-relationships of criteria and their levels. These criteria have also been categorized depending on their driving power and dependence.

There are various steps to follow when developing ISM models as follows.

Step 1: - identify barriers that affecting implementation of RL in Dire Dawa city all variables that affecting reverse logistic system

Step 2: - from listed variables above in step one, a contextual relationship is established.

Step 3: - then based on step two above, a structural self-interaction matrix (SSIM) is developed through considering pairwise relationships among variables of the system.

Step 4: -then reachability matrix is checked for transitivity. It states that if a variable A is related to B and B is related to C, then A is necessarily related to C.

Step 5: - the reachability matrix obtained in step 4 is subdivided into different levels.

Step6: - based on the relationships given above in the reachability matrix, a directed graph is drawn and the transitive links are removed.

Step 7: - the result digraph is transformed into an ISM, by changing variable nodes with statements

Step 8: - the ISM model developed in step 7 is reviewed to check for conceptual inconsistency and necessary modifications are made.

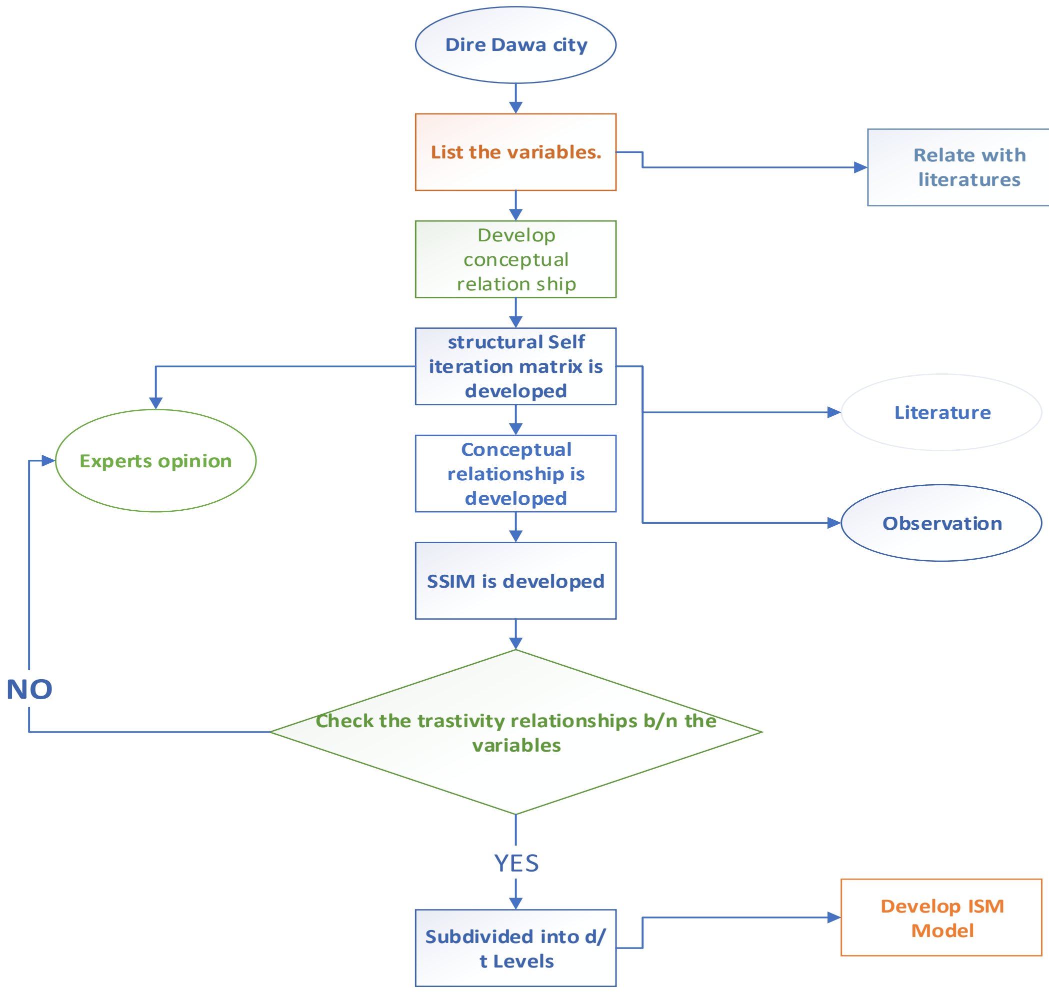


Figure 14 Diagram to follow for Developing ISM model

Source: - own (adopted from Ravi and Shankar, 2004)

4.2.2. Structural self-interaction matrix

SSIM methodology suggests the use of the expert opinions in developing the contextual relationship among the variables based on the various management techniques such as brain storming, nominal technique, etc., which is used for developing the contextual relationship among the variables. Thus, in this research for identifying the contextual relationship among the barriers of the reverse logistics, 4 people from plastic bottling company, 2 from small and medium intersperse, 3 from Dire Dawa city sanitation and beauty agency were accessed for this issue.

Table 6 structural self-interaction matrix (SSIM)

Barriers	13	12	11	10	9	8	7	6	5	4	3	2
1. Government regulation	A	V	V	A	X	V	V	X	A	V	V	X
2. Lack of information about RL	X	A	A	V	A	A	V	X	X	O	X	-
3.Attitude of the people	A	A	V	V	X	X	V	O	X	V	-	
4. Problems with product quality	O	A	O	A	V	V	V	V	A	-		
5. Company policy	A	O	A	V	O	V	V	A	-			
6. Struggle to change activities related to RL	A	A	A	V	A	X	X	-				
7. Lack of appropriate performance matrix	O	O	A	V	A	O	-					
8.Lack of training related to RL	A	A	O	V	V	-						
9. Lack of top management commitment	V	V	V	V	-							
10.Reluctance of the support of distributer, retailer and dealers	A	X	X	-								
11.Lack of awareness and education about RL	A	A	-									
12. Lack of strategic planning	V	-										
13. Financial constraint	-											

Following above tables, easily the reachability matrix for each variable and their existence of a relation between any two barriers (i and j) the associated direction of the relation is questioned. For the case, four symbols are used to represent the direction of relationship between the barriers (I and j).

V: - Barriers i will help alleviate Barrier j

A: - Barrier j will be alleviated by Barrier i

X; - Barrier i and j will help achieve each other and

O; - Barrier i and j are unrelated according to review of (Kannan 2009).

4.2.3. Reachability matrix

Lastly adopting the above methodology, transforming the above reachability matrix into binary matrix through substituting V, A, X, O by 1 and 0 as per the case. The rules for substitution of 1's and 0's is the following.

- If the (i, j) entry in the SSIM is V then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0
- If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j,i) entry becomes 1
- If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 1
- If the (i j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0

All these rules, initial reachability matrix for the barriers is shown in the table below as follows

Table 7 Initial reachability matrix

Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	Driver power
1. Government regulation	**1**	0	1	1	0	1	1	0	1	0	0	1	1	**8**
2. Lack of information about RL	0	**1**	1	0	1	1	1	0	0	1	0	0	0	**6**
3.Attitude of the people	0	1	**1**	1	1	0	1	1	1	1	1	0	0	**9**
4. Problems with product quality	0	0	0	**1**	0	1	1	1	1	0	0	0	0	**5**
5. Company policy	1	1	1	1	**1**	1	1	1	0	1	0	0	0	**9**
6. Struggle to change activities related to RL	1	1	0	0	0	**1**	1	1	0	1	0	0	0	**6**
7. Lack of appropriate performance matrix	0	0	0	0	0	0	**1**	0	0	0	0	0	0	**1**
8. Lack of training related to RL	1	1	1	0	0	1	0	**1**	0	1	0	0	0	**6**
9. Lack of top management commitment	1	1	1	0	0	1	1	1	**1**	0	1	1	1	**10**
10. Reluctance of the support of distributer, retailer and dealers	1	0	0	1	0	0	1	0	1	**1**	0	1	0	**6**
11. Lack of awareness and education about RL	1	1	0	0	1	1	1	1	0	1	**1**	1	0	**9**
12. Lack of strategic planning	0	1	1	1	0	1	0	1	0	1	0	**1**	1	**8**
13. Financial constraint	0	1	1	0	1	1	0	1	0	1	1	0	**1**	**8**
Dependence power	**7**	**9**	**8**	**6**	**5**	**10**	**10**	**9**	**5**	**9**	**4**	**5**	**4**	

Level partitions

According to Warfield (1974) reviews, the reachability and antecedent set for each barrier is found out from final reachability matrix. The reachability set for a particular variable consists of the variable itself and the other variables, which it may help achieve. The antecedent set consists of the variable itself and the other variables, which may help in achieving them. Subsequently, the intersection of these sets is derived for all variables. The variable for which the reachability and the intersection sets are the same is given the top-level variable in the ISM hierarchy, which would not help achieve any other variable above their own level. After the identification of the top-level element, it is discarded from the other remaining variables.

Table 8 partition of Reachability matrix: Iteration 1

BARRIERS	REACHABILITY SET	ANTECEDENT SET	INTERSECTIO N	LEVEL
1	1, 3, 4, 6,7, 9, 12, 13	1, 5, 6, 8, 9, 10, 11,	1, 6, 9	
2	2, 3, 5, 6, 7, 10	2, 3, 5, 6, 8, 11, 12, 13	2, 3, 5, 6	
3	2, 3, 4, 5, 7, 8, 9, 10, 11, 12	1, 2, 3, 5, 8, 9, 12, 13	2, 3, 5, 8, 9, 12	
4	4, 6, 7, 8, 9	1, 3, 4, 5, 10, 12	4	
5	1, 2, 3, 4, 5, 6, 7, 8, 10	2, 3, 5, 11, 13	2, 3, 5	
6	1, 2, 6, 7, 8, 10	1, 2, 4, 5, 6, 8, 9, 11, 12, 13	1, 2, 6, 8	
7	7	1, 2, 3, 4, 5, 6, 7, 9, 10, 11	7	I
8	1, 2, 3, 6, 8, 10	3, 4, 5, 6, 8, 9, 11, 12, 13	3, 6, 8	
9	1, 2, 3, 6, 7, 8, 9, 11, 12, 13,	1, 3, 4, 9, 10	1, 3, 9	
10	1, 4, 7, 9, 10, 12	2, 3, 5, 6, 8, 10, 11, 12, 13	10,12	
11	1, ,2, 5, 6, 7, 8, 10, 11,12	9, 11, 13	11	
12	2, 3, 4, 6, 8, 10, 12, 13	1, 9, 10, 11, 12	10, 12	
13	2, 3, 5, 6, 8, 10, 11, 13	1, 9, 12, 13	13	

As shown on table above, it is seen that lack of performance metrics (Barrier 7) is found at Level I. Thus, it would be situated at the top of the ISM model and the identified level is run out from the iteration and their rest is continuous till the levels of each variable are found out.

Iteration 2

BARRIER S	REACHABILITY SET	ANTECEDENT SET	INTERSECTIO N	LEVEL
1	1, 3, 4, 6, 9, 12, 13	1, 5, 6, 8, 9, 10, 11,	1, 6, 9	
2	2, 3, 5, 6, 10	2, 3, 5, 6, 8, 11, 12, 13	2, 3, 5, 6	
3	2, 3, 4, 5, 8, 9, 10, 11, 12	1, 2, 3, 5, 8, 9, 12, 13	2, 3, 5, 8, 9, 12	II
4	4, 6, 8, 9	1, 3, 4, 5, 10, 12	4	
5	1, 2, 3, 4, 5, 6, 8, 10	2, 3, 5, 11, 13	2, 3, 5	
6	1, 2, 6, 8, 10	1, 2, 4, 5, 6, 8, 9, 11, 12, 13	1, 2, 6, 8	

8	1, 2, 3, 6, 8, 10	3, 4, 5, 6, 8, 9, 11, 12, 13	3, 6, 8	
9	1, 2, 3, 6, 8, 9, 11, 12, 13,	1, 3, 4, 9, 10	1, 3, 9	
10	1, 4, 9, 10, 12	2, 3, 5, 6, 8, 10, 11, 12, 13	10,12	
11	1, ,2, 5, 6, 8, 10, 11,12	9, 11, 13	11	
12	2, 3, 4, 6, 8, 10, 12, 13	1, 9, 10, 11, 12	10, 12	
13	2, 3, 5, 6, 8, 10, 11, 13	1, 9, 12, 13	13	

Iteration 3

BARRIERS	REACHABILITY SET	ANTECEDENT SET	INTERSECTION	LEVEL
1	1, 4, 6, 9, 12, 13	1, 5, 6, 8, 9, 10, 11,	1, 6, 9	
2	2, 5, 6, 10	2, 5, 6, 8, 11, 12, 13	2, 3, 5, 6	III
4	4, 6, 8, 9	1, 4, 5, 10, 12	4	
5	1, 2, 4, 5, 6, 8, 10	2, 5, 11, 13	2, 5	
6	1, 2, 6, 8, 10	1, 2, 4, 5, 6, 8, 9, 11, 12, 13	1, 2, 6, 8	III
8	1, 2, 6, 8, 10	4, 5, 6, 8, 9, 11, 12, 13	6, 8	
9	1, 2, 6, 8, 9, 11, 12, 13,	1, 4, 9, 10	1, 9	
10	1, 4, 9, 10, 12	2, 5, 6, 8, 10, 11, 12, 13	10,12	
11	1, ,2, 5, 6, 8, 10, 11,12	9, 11, 13	11	
12	2, 4, 6, 8, 10, 12, 13	1, 9, 10, 11, 12	10, 12	
13	2, 5, 6, 8, 10, 11, 13	1, 9, 12, 13	13	

Iteration 4

BARRIERS	REACHABILITY SET	ANTECEDENT SET	INTERSECTION	LEVEL
1	1, 4, 9, 12, 13	1, 5, 8, 9, 10, 11,	1, 9	IV
4	4, 8, 9	1, 4, 5, 10, 12	4	
5	1, 4, 5, 8, 10	5, 11, 13	5	
8	1, 8, 10	4, 5, 8, 9, 11, 12, 13	8	
9	1, 8, 9, 11, 12, 13	1, 4, 9, 10	1, 9	
10	1, 4, 9, 10, 12	5, 8, 10, 11, 12, 13	10,12	IV
11	1, 5, 8, 10, 11,12	9, 11, 13	11	
12	4, 8, 10, 12, 13	1, 9, 10, 11, 12	10, 12	1V
13	5, 8, 10, 11, 13	1, 9, 12, 13	13	

Iteration 5

BARRIERS	REACHABILITY SET	ANTECEDENT SET	INTERSECTION	LEVEL
4	4, 8, 9	4, 5,	4	
5	4, 5, 8	5, 11, 13	5	
8	8	4, 5, 8, 9, 11, 13	8	V

9	8, 9, 11, 13	4, 9,	9
11	5, 8, 11	9, 11, 13	11
13	5, 8, 11, 13	9, 13	13

Iteration 6

BARRIERS	REACHABILITY SET	ANTECEDENT SET	INTERSECTION	LEVEL
4	4, 9	4, 5,	4	VI
5	4, 5	5, 11, 13	5	VI
9	9, 11, 13	4, 9,	9	
11	5, 11	9, 11, 13	11	
13	5, 11,	9, 11	11	VI

Iteration 7

BARRIERS	REACHABILITY SET	ANTECEDENT SET	INTERSECTION	LEVEL
9	9, 11	9,	9	VIII
11	11	9, 11	11	VII

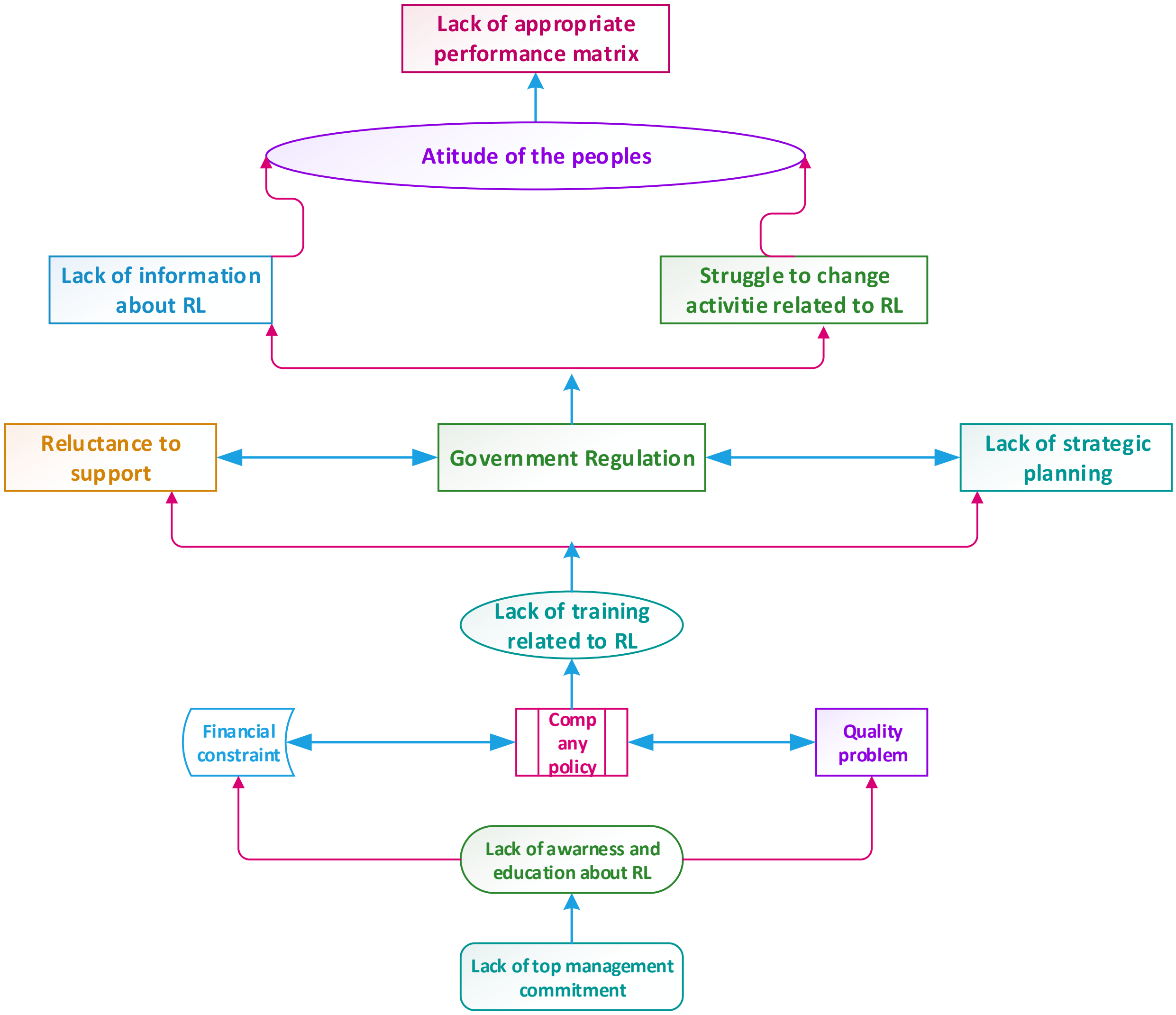
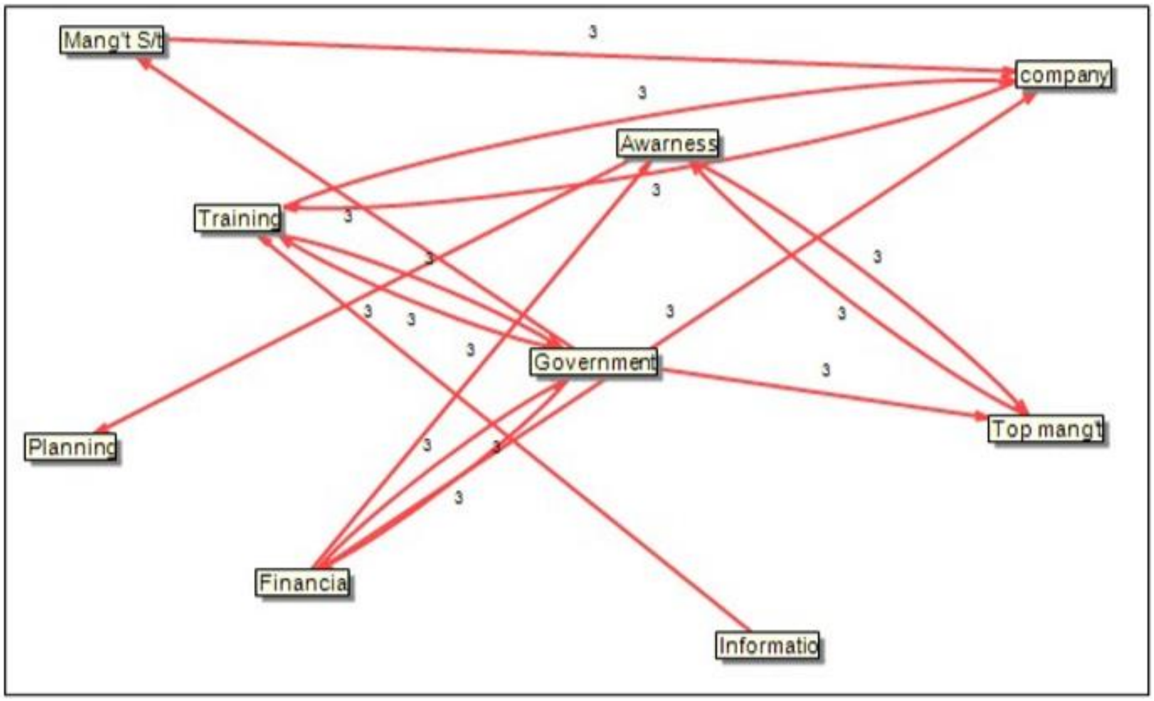


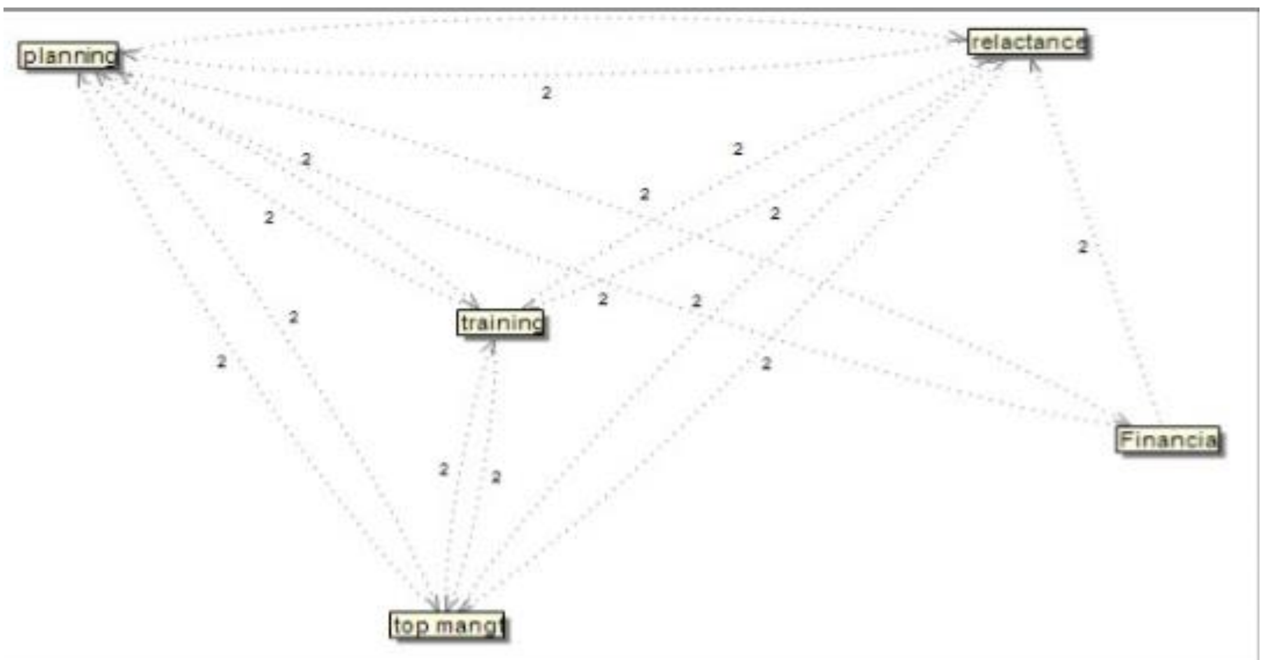
Figure 15 ISM Based model for the barriers of RL (Original idea adopted from Ravi and Shankar, 2004)

Summary

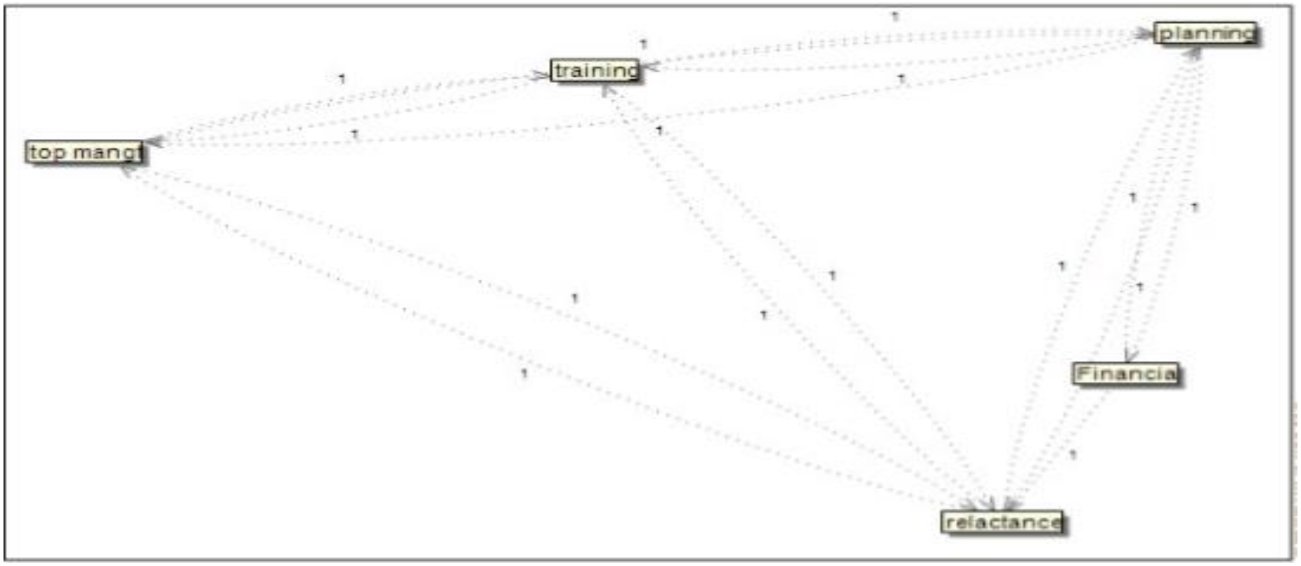
Based on the adaptation of interpretive structural modeling methodology, lack of awareness about reverse logistic was found to be the most influential barrier that was affecting to implement the system (Ravi and Shankar 2004). But in this study, top management is the most influential barrier that is affecting reverse logistic system in Dire Dawa city.

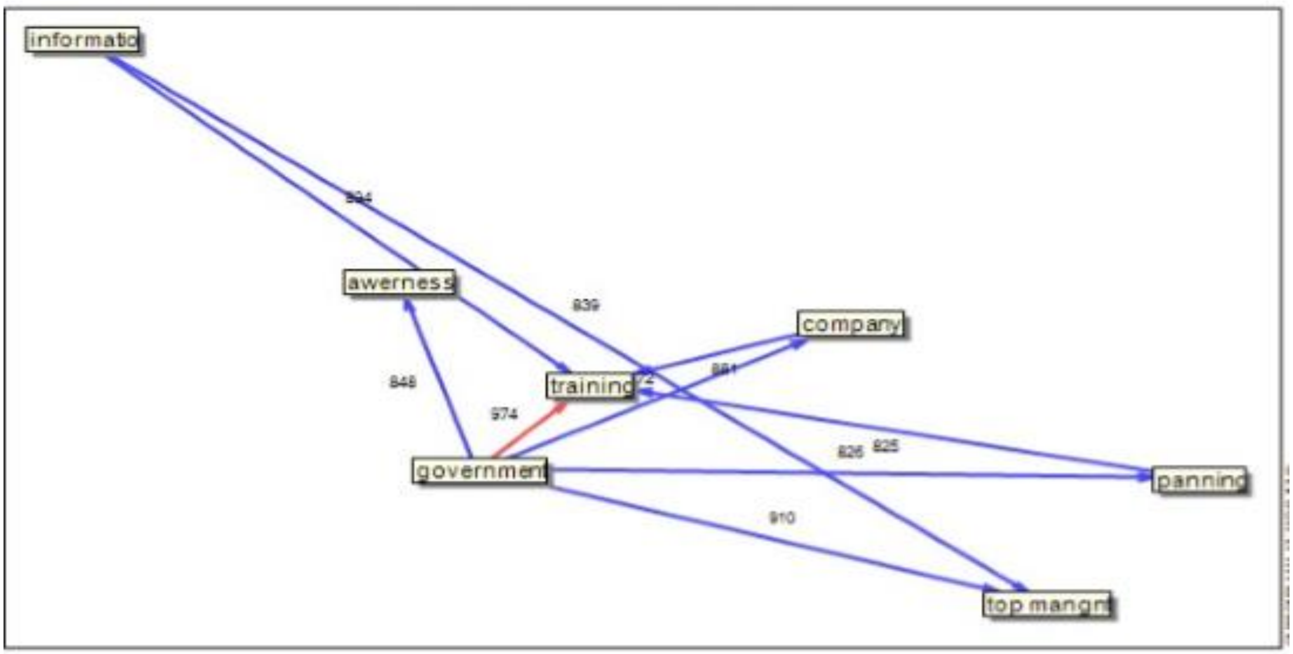
Graphics for Direct influence of the variables





Indirect influential graphics of the variables





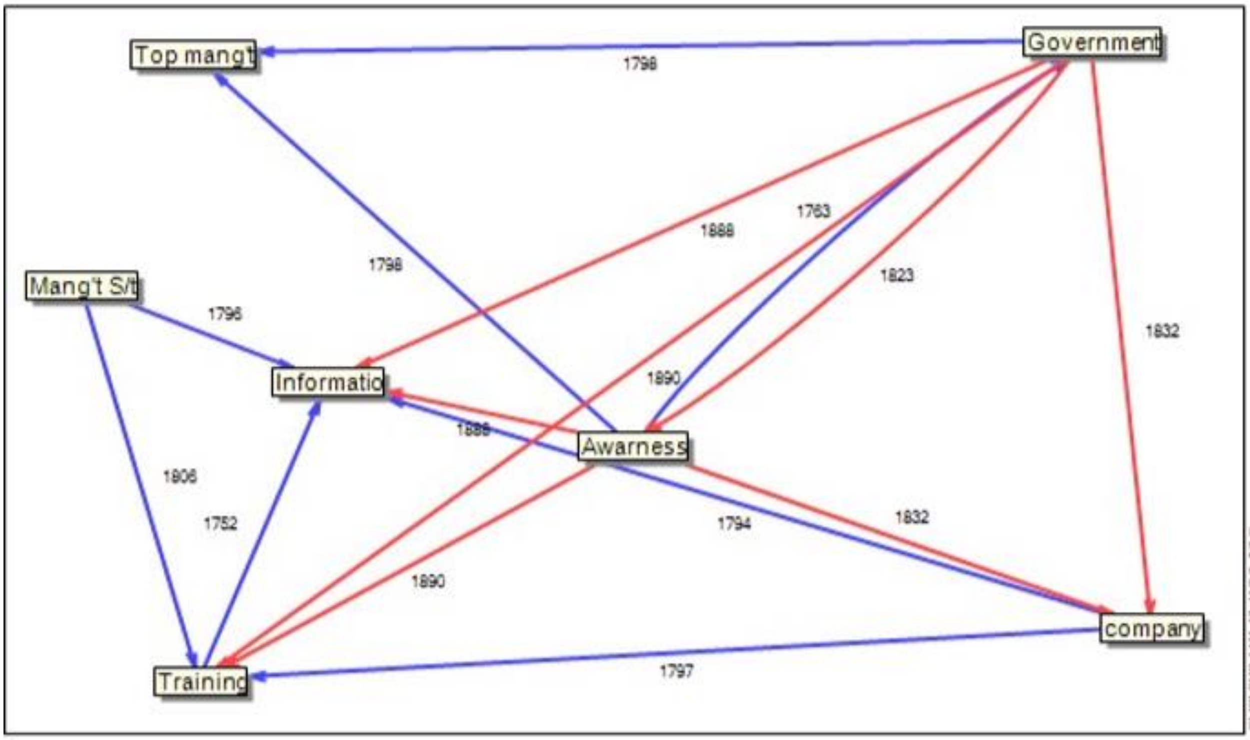


Figure 16 performance of the variable across each other's based on the reachability matrix

Table 9 Influential and Dependence performance of the variables

No. of iteration	Influential variable	Dependence variables
1	91%	98%
2	100%	98%

As the result indicates from MICMAC, the potential influential variables between the Barriers that affecting implementation of reverse logistic in dire Dawa city implies that 91% I first iteration and 100% influence each other in second iteration. But the Dependence variables in both iteration is similar which means 98% in each iteration**.**

4.3. Illustrated case study

This section is intending to present, analysis and interpretation of data which has been gained from both primary and secondary source of information and background analysis shown in the previous section. Therefore, the general objective of this chapter is to assess the existing practice and challenges of solid waste management (plastic bottles), indicate designs of relationship that exist among the data group and drawing conclusions from the collect data from all water bottling companies in Dire Dawa city.

4.3.1. Socio Economic and Demographic characteristics of respondent

The socio-economic structure of a given society is the most relevant issue to understand the practice of plastic bottle waste management and adopted the appropriate solid waste management system. Because consumption pattern, waste composition and generation, and disposal system could be conditioned to an important degree on the behavior, attitude, income, and awareness level of the society. As a result, assessing the socio economic and demographic variation is very crucial to point out baseline inform.

No.	Variables	Category	frequency	Percentages
1	Sex	Male	8	21.62
		Female	29	78.38
		Total	37	100
2	Age	18—25	9	24.32
		26—35	13	35.14
		36—45	8	21.62
		Above 45	7	18.92
		Total	37	100
3	Status of the respondents	Abel to read and write	6	16.22
		Primary school	12	32.43
		Secondary school	9	24.32
		Certificate	6	16.22
		Level or diploma	4	10.81
		Degree and above	2	5.4
		Total	37	100
4	Average monthly income	Below 1000	5	13.51
		1001—1500	8	21.62
		1501—2000	11	22.43
		2001---3000	7	18.92
		Above 3000	6	16.22
		Total	37	100

Table 10 Socio Economic and Demographic characteristics of respondents.

Source own survey (2018)

As shown on the above Social Economic and Demographic characteristics of respondents, the sex composition of respondents indicates that, the significant numbers respondents (78.38%) were female informant which is three-fold of male counterparts. Only 21.62% of the respondents were male respondents. This was due to females were mostly take parts in collecting waste from door to door and mostly worked on bottling company.

4.3.2. The practice of solid waste management in Dire Dawa city administration

Currently, the proper management of municipal solid waste grasps the attention of many cities in Ethiopia due to its environment, economic and health hazards. Studies on solid waste management in Ethiopian confirm that, in many cities of Ethiopia solid waste management practice lags behind the demand from the public. For instance, the study conducted by (Yami

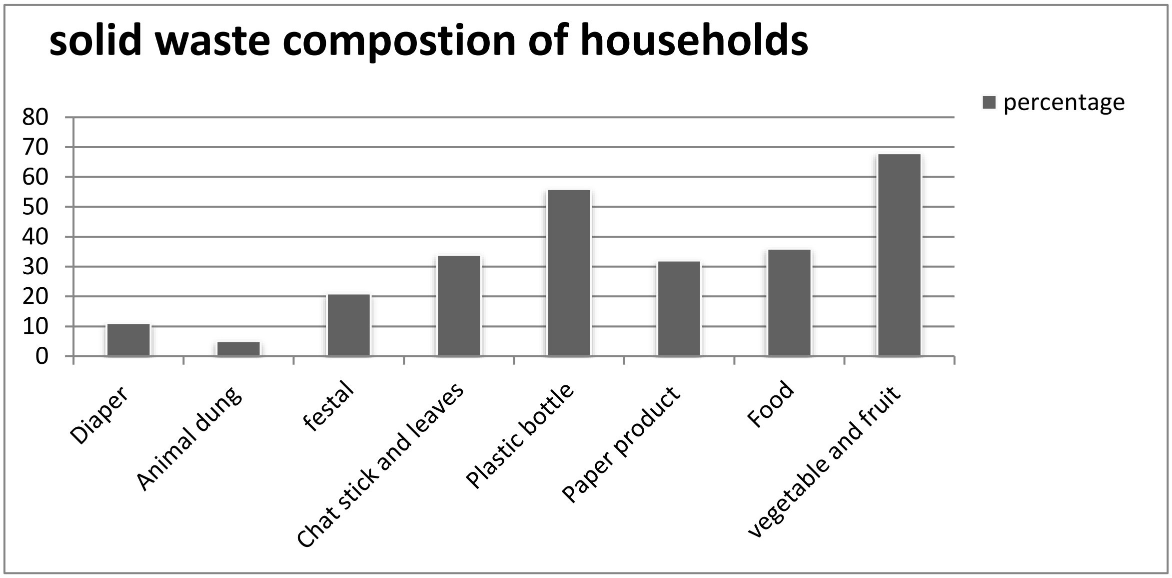
1999) indicates that in Ethiopia only 65% of the generated solid waste is collected and the remaining amount disposed illegally.

According to the revised institutional arrangement document of the city (2008 reporter) in Dire Dawa city administration municipal solid waste management service can't be equitably with the economic and population growth of the city. Therefore, in order to assess the existing practice of solid waste management, the researcher found out the following essential elements in order to describe the current solid waste management practice in the city; waste generation and composition, waste separation and storage, collection, transfer and transportation, and disposal as well as waste minimization the 3R approach (reduction, reuse and recycling).

4.3.4 Solid Waste Composition and Generation in the city

Having accurate and reliable data on solid waste combustion and generation is very essential to deliver effective solid waste management service. With respect to this issue (Rosenberg, et al 2013) said that data on composition and rate of generation is basic to design and operation of the functional elements associated with solid waste management.

Therefore, in order to understand the existing status of solid waste composition the respondents were asked a question "what type of solid waste you produce in your household?" and give the response by putting a mark in the boxes which constituent with "have" and "don't have" options in front of the types of municipal solid waste which could be produced in the city. The result presented in the following figure.



Source: own survey (2018)

Figure 17 solid waste composition of households

As shown on the above bar chart, the dominant number of respondents' which is above 65% of households' produce vegetable and fruit leftover coupled with house and yard sweeping frequently. Subsequently, plastic bottle produced around 58% of households. The other types of waste like, food left over, festal, paper product, and chat stick & leaves, animal dung, and diaper are produced in 34%, 32 % 33%, 5% and 11% of households respectively.

After identifying the type waste which is most frequently produced, the subsequent step is measuring the amount waste which is generated in given locality. According to Schubler et al. (1996) accurate information and reliable data on solid waste generation rate of different waste sources is essential in the selection of equipment and in the size of solid waste management.

Based on the information which is gained from document review, in the city, there is absence of reliable and accurate data on solid waste generation rate in general and municipal solid waste generation rate in particular. The data which estimated by different bodies lacks consistency. For instance, in 2004, the Dire Dawa health office estimate the solid waste generation rate to be about **0.5 kg/ cap/day**. Whereas according to the survey made by M.S consultancy in 2005, the waste generation rate of the city was estimated to be **0.30 kg/cap/day**. Moreover, the very recent integrated solid waste management plan study of city which is conducted by (Hilu 2006) estimated the daily solid waste generation rate **0.491kg/person/day** which is near to the estimation of Dire Dawa health office**.** This variation on the estimation of solid waste generation among the tree mentioned studies indicate that the data on solid waste generation rate of the city lacks reliability.

However, the study which is conducted by (Hilu 2006) Endev consultancy is the most recent one. Therefore, to estimate the daily solid waste generations' rate of the city, the researcher used this recent data. So that the daily House Hold solid waste generation rate of the city can be calculated by multiplying the city weighted average in kg/person/day by the number population in the city.

The daily average solid waste generation in kg/person/day $\times$ no population of 2010

0.491kg/capita/day $\times$369,674

181,509.934kg/day or

181.509 tons/day.

As the study indicated, in developing countries the average generation rate is in the range between 0.3 and 0.5 kg/ capita/day. Very recent estimation of solid waste generation rate of the city is closer to the highest range of waste generation rate in developing countries. Based on this information there is a highest generation rate in Dire Dawa city administration. Even this, there was no accurate or estimation data for plastic bottle waste in the city. But based on the respondents around 58% of household wastes was produced by plastic bottle.

4.3.5 Disposal Site

The disposal of waste by land filling or land spreading is the ultimate providence of all waste. With this regard Dire Dawa city has sanitary land filled which is 7 km far from the center located along Djibouti road. According to Edward et al. (2005) sanitary land filled refers to an engineered facility for the MSW designed and operated to minimize public health and environmental impact.

Figure 18 Dire Dawa landfill site, showing cell having solid waste mixed with liquid

In Dire Dawa, simple observation shows that the sanitary land filled site is not properly managed. In the sanitary land filled site the waste is spread, sealed in thin successive layer of the earth and compacted. However, solid waste is simply dumped and never leveled and also waste scattered in the compound. Even solid waste like plastic bottling, other solid waste and liquid was not separated just dumped illegally.

4.3.6 Sorting and Storage practice in the City

According to Dolfina et al. (2015)highlight the significance of sorting as follows. Storage and sorting have a significant effect on characterization of waste, on consequent functional element, on public health and on the public attitude concerning the operation of the waste management.

However, many empirical studies proofs that sorting and storage are neglected part of waste management in many developing countries. With this regard the researcher raised a general question which could indicate the overall sorting practice under this sub section and specific points under the section of waste minimization. Therefore, a detail practice of solid waste minimization presented under the sub topic of waste minimization in the city. So that the respondents were asked either they store solid waste separately or indiscriminately. The result is presented by using the following pie chart fig

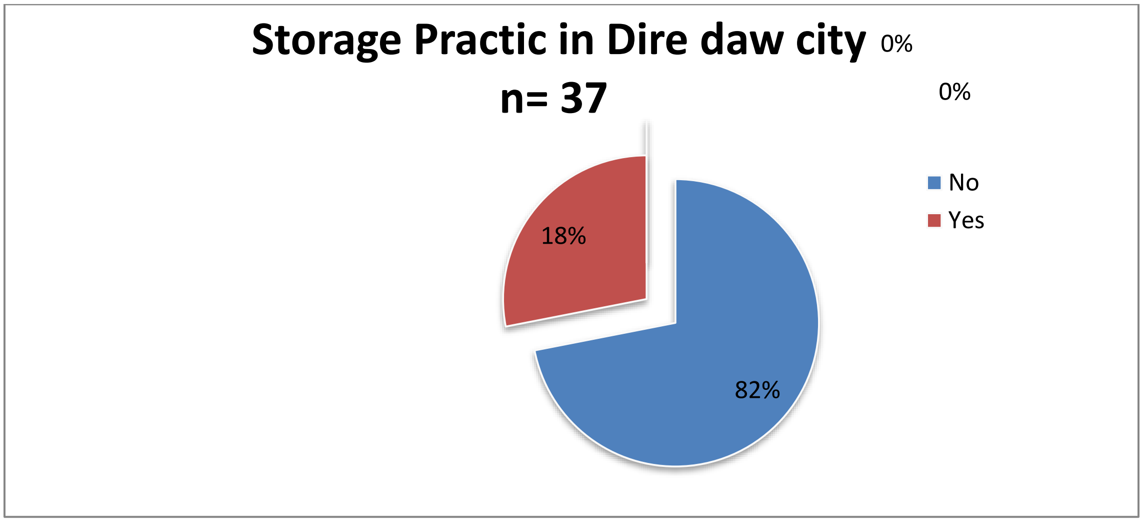


Figure 19 storage practice in Dire Dawa city

As shown above, the majority of respondents store solid wastes in discriminating. In 82% of households, all organic and in organic as well as recyclable and non-recyclable solid wastes are stored indiscriminately by using one storage material. The remaining 18% of the respondents stored solid wastes separately. With this regard, the interview result from the representative of the head of the agency is also support the survey result. According to the representative, the agency is putting an effort to implement the strategy of sorting practice, and it will be put in place recently. However, there was no strategy regarding sorting practice so far.

In general, based on the survey and observation result, one can be in the position that in the city the separation of wastes depends on their awareness about the usefulness of such rejected material for the informal sector and homemade purpose. The activity of sorting is not carried on separate standardized material and based on sufficient awareness on how to separate wastes and what kind of material should and could be separated.

4.3.7 Secondary Collection and Transportation

The common containers in Dire Dawa city Municipality Solid waste service is periodically picked, transported and emptied in to a poorly managed land filling disposal site using skip loaders owned by the City Administration. According to data obtained from Dire Dawa city sanitation and beauty agency. The distribution of skips by Kebele is shown in the table below.

Table 11 Distribution of containers in kebeles

Kebele	**Existing Number of Containers**	**Number of Households**	**Ratio of HH To Containers**
01Melka Jebdu	6	4,127	688
02 Sabean	17	12,380	728
03 Kezira	13	5213	410
04Ganda Kore	14	5,515	390
05 Ginfile	21	4809	229
06 Dechatu	19	4268	225
07 Afatessa	7	6,027	861
08 LagaHarre	8	7561	945
09 Police Maret	15	11,459	764
Total	120	61,359	511

Source:-(Dire Dawa city sanitation and beauty agency no.345/2008).

Above table shows an unfair distribution of containers across Kebeles. The distribution ranges from one container for every 225 households in Kebele 06 to one container for 945 households in Kebele 08 which have large varieties when comparing each kebeles. Providing of additional containers for making fair distribution and some redistribution seem necessary. During the present study, it was only two skip loaders was operating. With two skip loader the waste collection is found in a serious situation with low collection efficiency. Skips kept for over a week unemployed can be a serious health concern to the nearby habitants. Even this, there is no train to sorting plastic bottle form the household solid waste. Just dumping in irregular way to the city landfills.

4.4. production capacity of bottling company with respect to city consumption

Table 12 production capacity of Aqua UNO bottling company

No.	Types of product	Efficiency per 16 hrs.	Weekly production
1	0.3 lit. or 0.6	113,859lit. of bottles / a day	341,577 bottles / a week
2	1.0 lit.	102,000 lit. of bottles /a day	306,000 bottles / a week
3	1.5 lit.	79,200 lit. of bottles / a day	237,600 bottle / a week
4	2.0 lit.	63,360 lit. of bottle / a day	190,080 bottles / a week
		Total production per a week	**1,075,257 bottles / a week**

Number of plastic bottles defects in the company due to preform and bottling process. **161,288.55** defects of bottles per a week. Of the total production, 50% to 55% (**591, 391.35**) of their customer is Dire Dawa city and around rural population of the city and the rest customer is eastern part of Ethiopian peoples. Such as Harar, Jijga Wucale, Ciro, and the rest of Harari peoples were some of the UNO product customers today.

Therefore **161,288.55 + 591, 391.35 =<u>752,679.9</u>**bottles/week have been taken as assumption for recycling in the city.

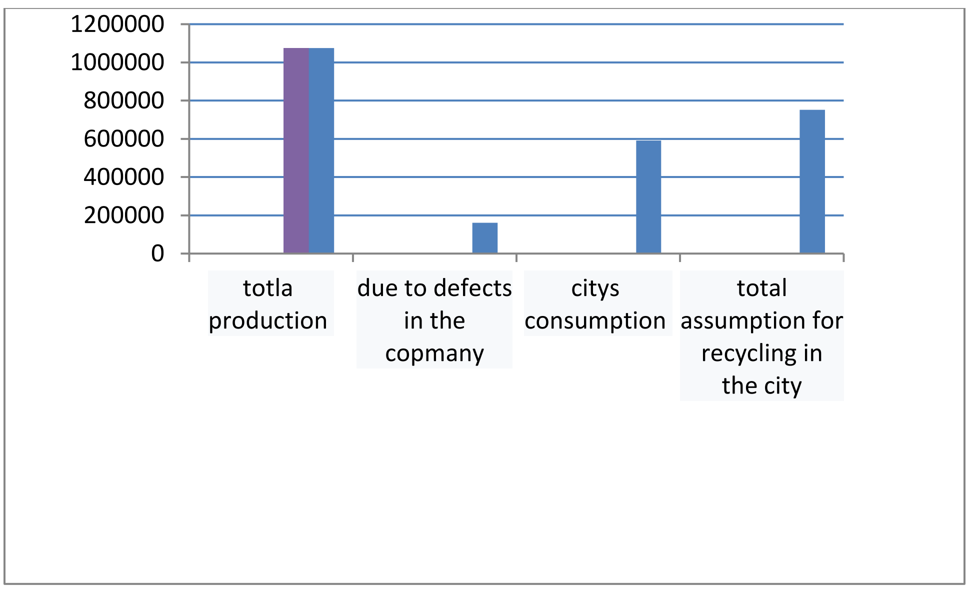


Figure 20 production capacity of Aqua UNO bottling company

Table 13 production capacity of Ayaan bottling company

No.	Types of product	Efficiency per 16 hrs.	Weekly production
	0.3 lit. or 0.6	160,000 lit. of bottles / a day	480,000 bottles / a week
	1.0 lit.	120,000 lit. of bottles / a day	360,000 bottles / a week
	1.5 lit.	88,000 lit. of bottles / a day	264,000 bottles / a week
	2.0 lit.	72,000 lit. of bottles / a day	216,000 bottles / a week
		Total production per a week	**1,320,000 bottles / a week**

Number of plastic bottles defects in the company due to preform and bottling process **198,000** defects of bottles per a week. Of the total production, 40% to 45% (**594,000**) of their customer is Dire Dawa city and around rural population of the city and the rest customer is eastern part of Ethiopian peoples. Such as Harar, Jijga, Wucale, Ciro, and the rest of Harari peoples, Arsi, Bale and Arba Minch were some of the Ayaan product customers today.

Therefore **198,000 + 594,000=792,000** bottles/week have been taken as assumption for recycling in the city.

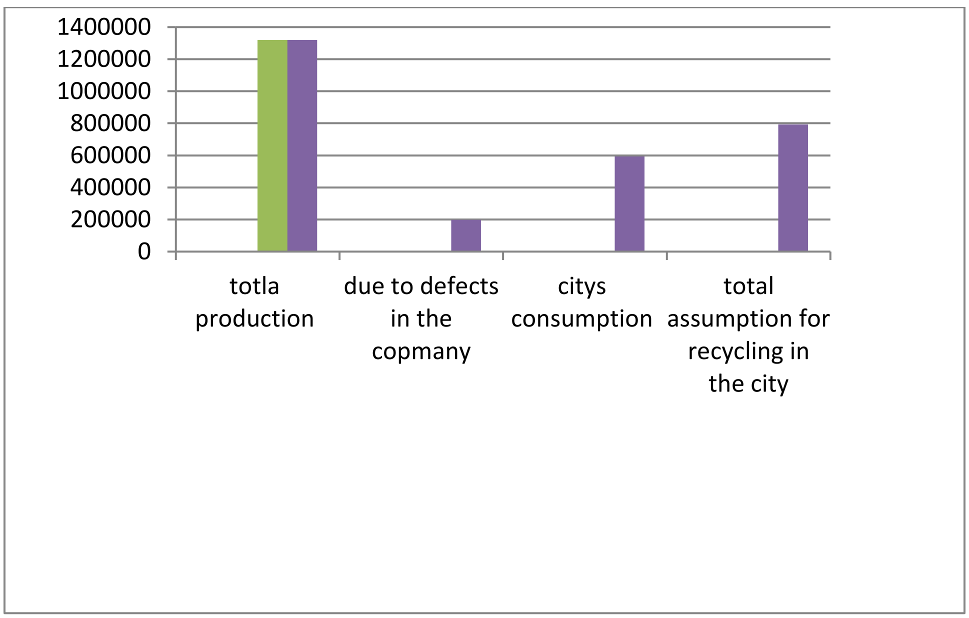


Figure 21 production capacity of Ayaan bottling company

Table 14 production capacity of Vita bottling company

No.	Types of product	Efficiency per 16 hrs.	Weekly production
1	0.5 Lit.	110,000 lit. of bottles / a day	330,000 bottles / a week
2	1.0 lit.	105,000 lit. of bottles / a day	315,000 bottles / a week
3	1.5 lit.	80,000 lit. of bottles / a day	240,000 bottles / a week
4	2.0 lit.	46,400 lit. of bottles / a day	139,200 bottles / a week
		Total production per a week	**1,154,400 bottles / a week**

Number of plastic bottles defects in the company due to preform and bottling process **defects** of **173,160** bottles per a week. Of the total production, 50% (**577,200**) of their customer is Dire Dawa city and around rural population of the city and the rest customer is eastern part of Ethiopian peoples. Such as Harar, Jijga, Wucale, Ciro, and the rest of Harari peoples were some of the Vita product customers today.

Therefore **173,160 + 577,200=750,360** bottles/week have been taken as assumption for recycling in the city.

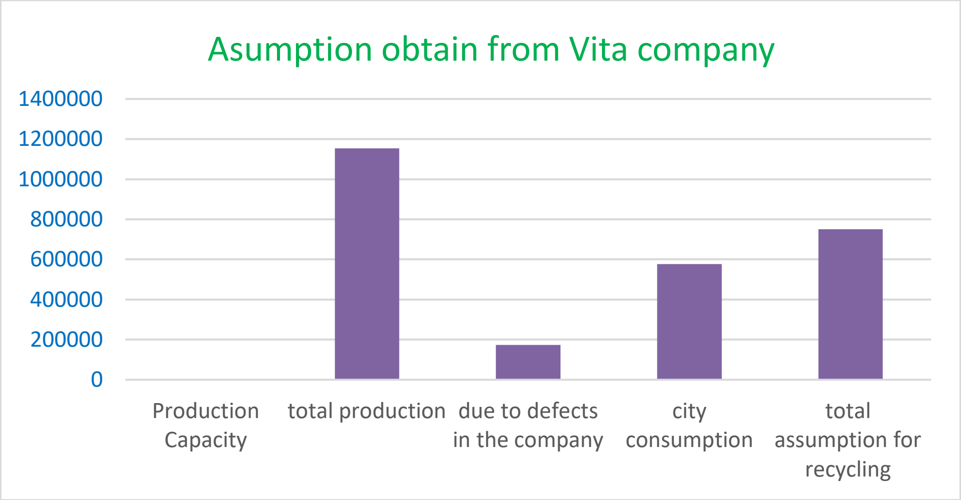


Figure 22 production capacity of Vita bottling company

Table 15 production capacity of Liban bottling company

No.	Types of product	Efficiency per 16 hrs.	Weekly production
1	0.5 Lit.	125,000 lit. of bottles / a day	375 ,000 bottles / a week
2	1.0 lit.	110,800 lit. of bottles / a day	332,400 bottles / a week
3	1.5 lit.	80,900 lit. of bottles / a day	242,700 bottles / a week
4	2.0 lit.	57,500 lit. of bottles / a day	172,500 bottles / a week
		Total production per a week	**1,122,600 bottles / a week**

Number of plastic bottles defects in the company due to preform and bottling process **defects** of **168,390** bottles per a week. Of the total production, 50% to 55% (**617,430**) of their customer is Dire Dawa city and around rural population of the city and the rest customer is eastern part of Ethiopian peoples. Such as Harar, Jijga, Wucale, Ciro, and the rest of Harari peoples and Djibouti were some the Liban product customers.

Therefore **168,390** + **617,430** = **785,820** bottles/week have been taken as assumption for recycling in the city.

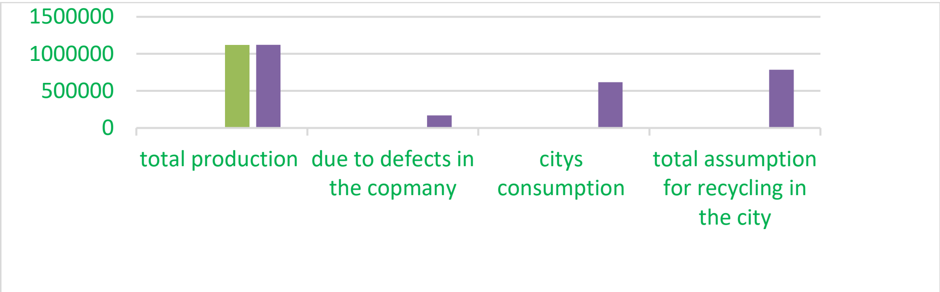


Figure 23 production capacity of Liban bottling company

Table 16 production capacity of Aqua Dire bottling company

No.	Types of product	Efficiency per 16 hrs.	Weekly production
1	0.5 Lit.	88,092 lit. of bottles / a day	264,276 bottles / a week
2	1.0 lit.	34,560 lit. of bottles / a day	103,680 bottles / a week
3	1.5 lit.	26,580 lit. of bottles / a day	79,740 bottles / a week
4	2.0 lit.	20,784 lit. of bottles / a day	62,352 bottles / a week
		Total production per a week	**510,048 bottles / a week**

Number of plastic bottles defects in the company due to preform and bottling process **defects** of **76,507.2** bottles per a week. Of the total production, 50% to 55% (**280,526.4**) of their customer is Dire Dawa city and around rural population of the city and the rest customer is eastern part of Ethiopian peoples. Such as Harar, Jijga, Wucale, Ciro, and the rest of Harari and Somali peoples were some the Aqua Dire product customers.

Therefore **76,507.2** + **280,526.4** = **357,033.6** bottles/week have been taken as assumption for recycling in the city.

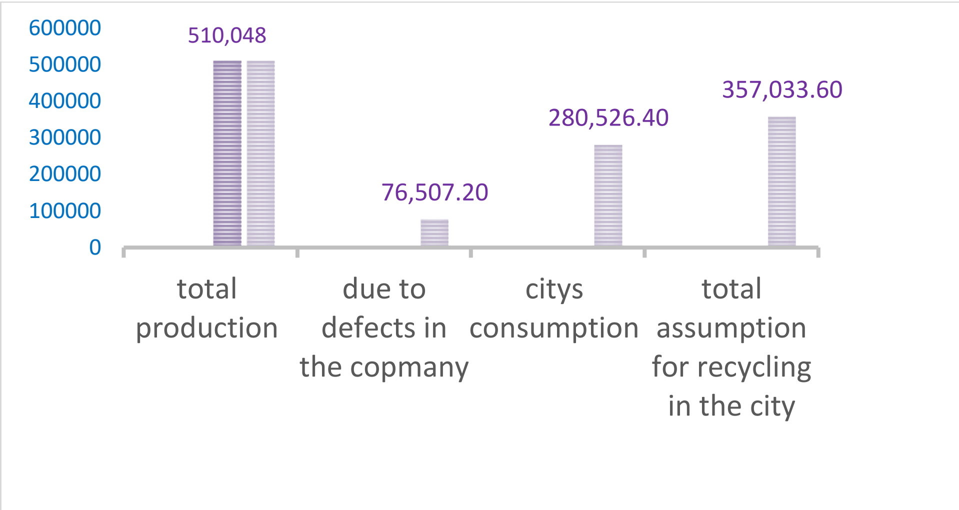


Table 17 production capacity of Aqua Dire bottling company

Table 18 average number of bottles from the agent

No.	Name of Agents	Capacity
1	Aqua Addis	48,000
2	Gift	25,000
3	One One	28,000
4	Yes Yes	55,000
	Total	**148,000** bottles in average / a week

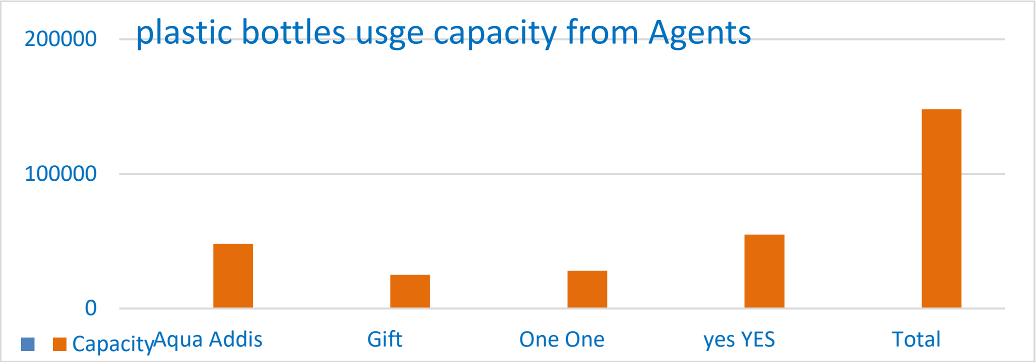


Figure 24 average number of bottles from the agent

Summary

Table 19 total number of plastic bottle taken as assumption for recycling in Dire Dawa city.

No.	Company name	Number of bottles taken as assumption for recycling per a week
1	Aqua uno	752,679.9
2	Ayaan	792,000
3	Vita	750,360
4	Liban	785,820
5	Aqua Dire	357,033.6
6	From Agents	148,000
	Total	**3,585 ,893.5**

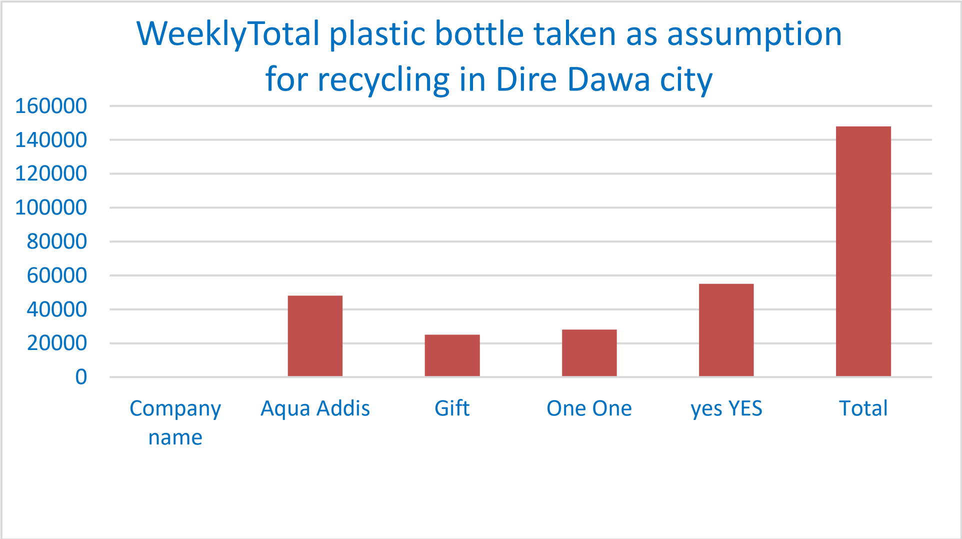


Figure 25 total number of plastic bottle taken as assumption for recycling in Dire Dawa city

4.5. Developing the analyze through other related study cases

4.5.1 PET and HDPE

PET (polyethylene terephthalate) is the best known as the clear plastic used for water and soda container, it is globally recognized as safe nontoxic strong, light flexible material that is 100% recyclable. which is used to produce preform for the plastic bottle both flat water and carbonated soft drinks.

Figure 26 preform production

(source from Copa impact PLC Recycling Company)

Figure 27 scrap perform

(source from Copa impact PLC Recycling Company)

The manufacturing company produces preform by importing virgin materials and provides to the bottler company. The bottler company sale the scrap preforms for any collection association and for those recycling bottler companies to use as raw material for recycling.

HDPE Closure is made up of good quality plastic materials, which do not react with the contents and are resistant to stress cracking. These products are manufactured using hi-tech technology to ensure tight seal of the bottles.

The small pieces, labels and the closure protective HDPE will further have used as energy through replacing charcoal energy for Cement factory.


Source: -https://www.google.com/image

RECYCLING


Source: -https://www.google.com/image

Figure 28 collected plastic Bottles and Bales

The raw material that feeds the industry of recycled plastic bottles from households, big hotels, higher institutions, bottlers, pickers etc. has a prime importance and that needs systematic way to feed the necessary amount.

4.5.2. Description of the machine

The IPS series of injection presses is specially designed to produce thermoplastic preforms by means of injection.

The main machine components are

- Injection unit
- Press unit
- Handling unit
- Conveyor belts
- Hydraulic system
- Cooling system, Pneumatic system and Electrical system

Recycling Machines

Hydraulic PET Bottle Baling Machine with Single Cylinder, which is located at collection center, those pressing machines make transportation easy by compress bottles and also if the bottles not compressed they are not easy to crush the bounce in cutting chamber.

Figure 29 pressing machine *Figure 30 pressed bottles (bales)*

According to Costa (2014) reviewed, based on the Assumption 2, The weighted average for a PET container is **38.725** grams/unit. This is based on weight-to-unit conversion data from the

Manitoba Product Stewardship Corporation (MPSC) representing all PET beverage containers, which is based on a mix of units of various size.

Based in this assumption, weekly capacity of plastic Bottles obtains on table summary (19) above shows that **3,585 ,893.5** weekly plastic bottles/unit are ready for recycling. Which is around **138,863,726 grams/unit** or **138,863.726 kg** of plastic bottle is weekly collected.

According data obtained from company's report (27/2010) and through interviewing with company's collection managers, 1kg of Baling Plastic Bottles price would be 7-8 Ethiopia Birr. But if it was not Baled the price would be taken to decrement 3- 4 Birrs.

Therefore, this research persists to collecting plastic Bottles from all association, institutes, street children's from, schools and university's through different means for pressing and Baling it. because it is difficult for transportation to supply aid as it is. So, based on the information obtained from Copa Impact recycling company, cost analysis was as follows.

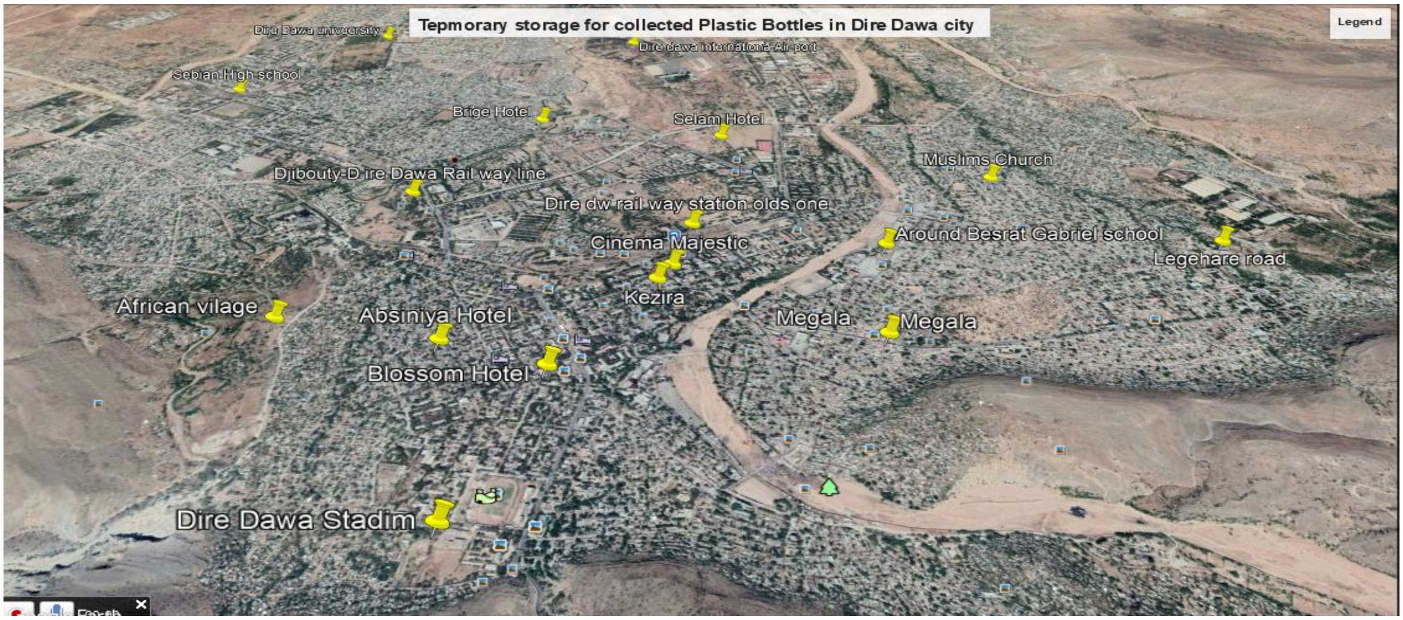
Weekly collection = **138,863.726 kg** of plastic bottles.

Price for Baling one =**8 birr / kg** which is

=1,110,909.81 Birr or

$ 41,144.8078[1]per week=**$ 164,579.231**monthly

(Assuming and using the daily Ethiopian commercial bank exchange rate, 1USD=27.00 Birr).



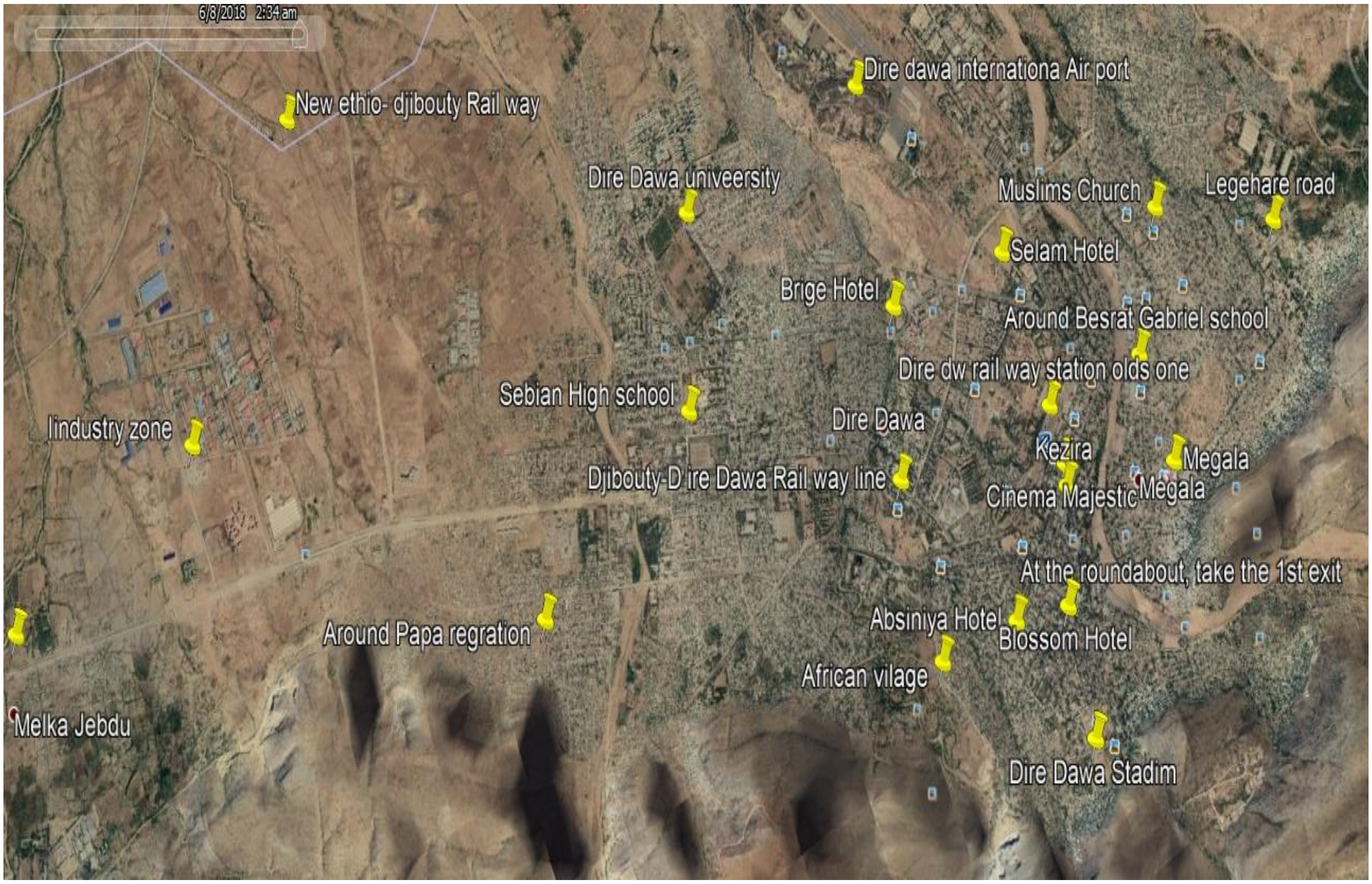


Figure 31 Location for collecting, temporarily storage and Baling and pressing area

The optimum collection network developed on the above google map, has been based on Constraints such as Population size, Government institution, Industry zone, Industry park, University, Hospital, some Religious area, Hotels and some Grocery, Schools and Colleges, and other areas in which mostly the consumption of plastic Bottles has been increased.

Table 20 input parameters for proposed network development.

NO.	***Collection-center***	***Latitude***	***longitude***	***Generating sites***
1	CC1	9°35'23.46"N	41°52'6.12"E	Feresmegala
2	CC2	9°36'41.15"N	41°51'5.57"E	Dire dawa university
3	CC3	9°36'28.80"N	41°50'35.57"E	Sebyian high school
4	CC4	9°37'8.81"N	41°48'41.18"E	Industry zone
5	CC5	9°36'19.51"N	41°48'20.78"E	MelkaJebdu
6	CC6	9°36'52.43"N	41°50'45.35"E	Dire dawa international Air port
7	CC7	9°36'13.82"N	9°36'13.82"N	Around Besrat Gabriel school
8	CC8	9°36'3.55"N	41°51'25.53"E	Selam Hotel
9	CC9	9°36'0.83"N	41°51'20.94"E	African village
10	CC10	9°35'47.95"N	41°51'20.48"E	Legehare road
11	CC11	9°34'36.76"N	41°51'18.65"E	Dire Dawa Stadium
12	CC12	9°36'7.27"N	41°49'21.44"E	Around Papa regration
13	CC13	9°35'50.87"N	41°50'57.00"E	Dire dawa rail way station old's one
14	CC14	9°35'12.93"N	41°51'28.80"E	Blossom Hotel
15	CC15	9°35'34.89"N	41°51'39.24"EE	Cinema Majestic
16	CC16	9°36'5.31"N	41°52'23.19"E	Muslims Church
17	CC17	9°35'16.16"N	41°51'15.26"E	Absiniya Hotel
18	CC18	9°35'31.33"N	41°51'37.92"E	Kezira

Table 21 input parameters obtained from Google Earth

From Destination	To Destination	Time taken between the destination	Distance taken between the destination	Cost per distance travel
Kezira place of temporary pressing and Baling plastic Bottles	Feres megala	11	5.3 km	3.18
	Dire dawa university	16	5.9 km	3.54
	Sebyian high school	12	5.4 km	3.24
	Industry zone	18	8.7 km	5.22
	Melka Jebdu	20	9.2 km	5.52
	Dire Dawa international Air port	12	4.5 km	2.7
	Around Besrat Gabriel school	17	6 km	3.6
	Selam Hotel	5	1.5 km	0.9
	African village	12	4.6 km	2.76
	Leg hare road	7	2.3 km	1.38
	Dire Dawa Stadium	5	1.6 km	0.96
	Around Papa recreation	12	3.8 km	2.28
	Dire dawa rail way station olds on	6	2.1 km	1.26
	Blossom Hotel	8	2.7 km	1.62
	Cinema Majestic	11	5.3 km	3.18
	Muslims Church	14	5.7 km	3.42
	Abyssinia Hotel	13	5.6 km	3.36

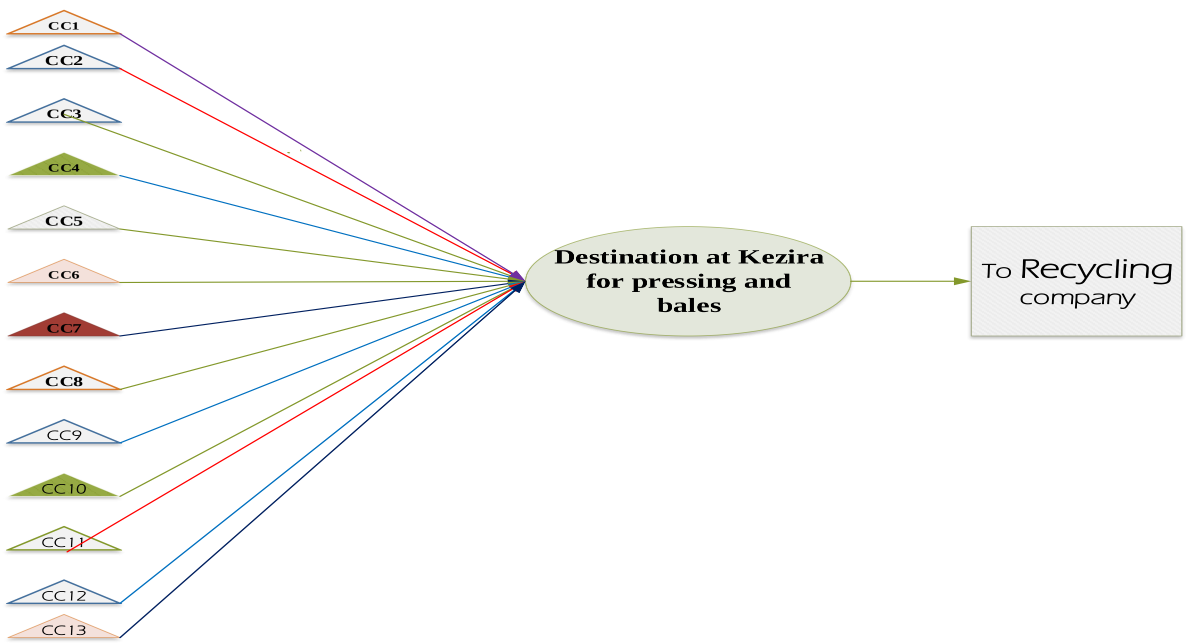


Figure 32 From Optimum collection center to destination at kezira

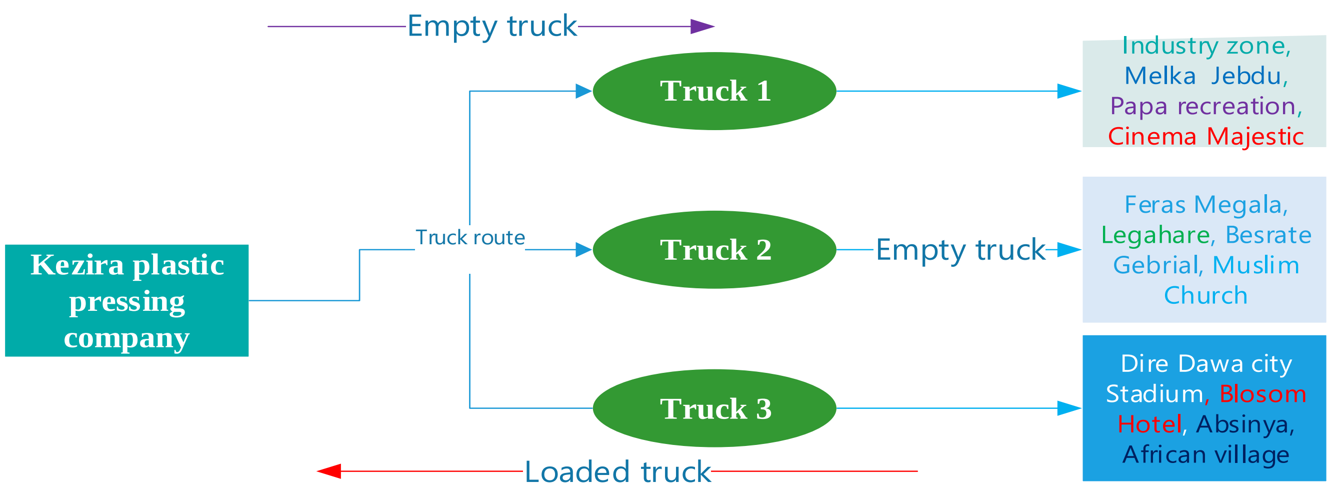


Figure 33 the optimum truck route from all destination

Table 22 the optimum truck route from all destination

s.no	Operational tasks	Unit per costs	Total costs
1	Transportation	3,500 *2	7,500
2	Labor	8 *1800	14,400
3	Awareness creation (it depends)	2000	2000
4	Temporary Employee	6 * 2000	12,000
5	Truck rent	30,000 *2	60,000
5	Electric power (it depends)	1500	1500
6	Water power (it depends)	500	500
7	Promotion (it depends)	10,000	10,000
8	Baling ware	270 *6	1,620
9	Maintenance	1000	1000
10	Other costs 15%	15,078	15,078
11	Tax (it depends)	15,078	15,078
	Total cost		**115,598**

From the above table, the total cost invested for collecting and baling process is about **115,598** birrs($ **4,281.407).** And this cost is consumed monthly for processing. Hence, the overall profit to be generated monthly can be calculated as follows.

Profit/ Month= Selling price of baled plastic bottle- Processing cost/ bailing cost

Overall profit= $ 164,579.231--$ 4,281.407=$ 160,297.824 monthly (Assumption of currency rate, 1USD=27.00Birr).

In order to find further benefits and showing optimal route design to reduce transportation cost, Linear programming (LP) model was formulated. The LP model was based on the capacity of the truck collected from temporary storage and all destination in the city.

The model is solved with LINGO 17and the result is presented as follows.

The optimum collection route for truck one

```
Feasible solution found.
Objective value:                              212.3049
Infeasibilities:                             0.3633982E-01
  Total solver iterations:                          364
  Elapsed runtime seconds:                         0.47

  Model Class:                                      NLP

                  Total variables:                    7
                  Nonlinear variables:                2
                  Integer variables:                  0
                  Total constraints:                  2
                  Nonlinear constraints:              1
                  Total non-zeros:                    4
                  Nonlinear non-zeros:                2

                       Variable           Value        Reduced Cost
                             TC        212.3049            1.000000
                         LATLAT        9.369996            0.000000
                       LONGLONG        41.48400            0.000000
          TRANSPORTATION_COST( CC4)    5.220000            0.000000
          TRANSPORTATION_COST( CC5)    5.520000            0.000000
         TRANSPORTATION_COST( CC12)    2.280000            0.000000
         TRANSPORTATION_COST( CC15)    3.180000            0.000000
                     QUANTITY( CC4)    1400.000            0.000000
                     QUANTITY( CC5)    1400.000            0.000000
                    QUANTITY( CC12)    1400.000            0.000000
                    QUANTITY( CC15)    1400.000            0.000000
                          LAT( CC4)    9.370000            0.000000
                          LAT( CC5)    9.370000            0.000000
                         LAT( CC12)    9.360000            0.000000
                         LAT( CC15)    9.350000            0.000000
                         LONG( CC4)    41.48200            0.000000
                         LONG( CC5)    41.48400            0.000000
                        LONG( CC12)    41.49200            0.000000
                        LONG( CC15)    41.51300            0.000000
                            D( CC4)    1.234568            0.000000
                            D( CC5)    1.234568            0.000000
                           D( CC12)    1.234568            0.000000
                           D( CC15)    1.234568            0.000000

                            Row    Slack or Surplus      Dual Price
                              1        212.3049           -1.000000
                              2      -0.3633982E-01        0.000000
```

The optimum collection route for truck Two

```
Feasible solution found.
Objective value:                              856.5671
  Infeasibilities:                             0.4928264E-02
  Total solver iterations:                           296
  Elapsed runtime seconds:                          0.47
  Model Class:                                       NLP
  Total variables:                    7
  Nonlinear variables:                2
  Integer variables:                  0

  Total constraints:                  2
  Nonlinear constraints:              1

  Total nonzeros:                     4
  Nonlinear nonzeros:                 2
                              Variable           Value        Reduced Cost
                                   TC        856.5671            1.000000
                               LATLAT        9.360000            0.000000
                             LONGLONG        41.52200            0.000000
             TRANSPORTATION_COST( CC1)       3.180000            0.000000
             TRANSPORTATION_COST( CC7)       3.600000            0.000000
            TRANSPORTATION_COST( CC10)       1.380000            0.000000
            TRANSPORTATION_COST( CC16)       3.420000            0.000000
                        QUANTITY( CC1)       1400.000            0.000000
                        QUANTITY( CC7)       1400.000            0.000000
                       QUANTITY( CC10)       1400.000            0.000000
                       QUANTITY( CC16)       1400.000            0.000000
                             LAT( CC1)       9.360000            0.000000
                             LAT( CC7)       9.360000            0.000000
                            LAT( CC10)       9.350000            0.000000
                            LAT( CC16)       9.360000            0.000000
                            LONG( CC1)       41.52600            0.000000
                            LONG( CC7)       41.36100            0.000000
                           LONG( CC10)       41.51200            0.000000
                           LONG( CC16)       41.52200            0.000000
                               D( CC1)       2.829380            0.000000
                               D( CC7)      0.5440688            0.000000
                              D( CC10)       789.6082            0.000000
                              D( CC16)      0.1491989            0.000000

                                   Row    Slack or Surplus      Dual Price
                                     1        856.5671           -1.000000
                                     2   -0.4928264E-02           0.000000
```

The optimum collection route for truck Three

```
Feasible solution found.
Objective value:                              54.48532
Infeasibilities:                             0.9938099E-01
  Total solver iterations:                         649
  Elapsed runtime seconds:                         0.51

  Model Class:                                      NLP

  Total variables:                    7
  Nonlinear variables:                2
  Integer variables:                  0

  Total constraints:                  2
  Nonlinear constraints:              1

  Total nonzeros:                     4
  Nonlinear nonzeros:                 2
```

Variable	Value	Reduced Cost
TC	54.48532	1.000000
LATLAT	9.350027	0.000000
LONGLONG	41.51103	0.000000
TRANSPORTATION_COST(CC9)	2.760000	0.000000
TRANSPORTATION_COST(CC11)	0.9600000	0.000000
TRANSPORTATION_COST(CC14)	1.620000	0.000000
TRANSPORTATION_COST(CC17)	3.360000	0.000000
QUANTITY(CC9)	1400.000	0.000000
QUANTITY(CC11)	1400.000	0.000000
QUANTITY(CC14)	1400.000	0.000000
QUANTITY(CC17)	1400.000	0.000000
LAT(CC9)	9.360000	0.000000
LAT(CC11)	9.340000	0.000000
LAT(CC14)	9.350000	0.000000
LAT(CC17)	9.350000	0.000000
LONG(CC9)	41.51200	0.000000
LONG(CC11)	41.51100	0.000000
LONG(CC14)	41.51200	0.000000
LONG(CC17)	41.51100	0.000000
D(CC9)	63595.98	0.000000
D(CC11)	183.1671	0.000000
D(CC14)	6.863507	0.000000
D(CC17)	396.2156	0.000000

Row	Slack or Surplus	Dual Price
1	54.48532	-1.000000
2	-0.9938099E-01	0.000000

From the above running of the model, linear transportation about truck routs in all destination, the rout is infeasible that means not at optimal. Based on the truck rout scenario, scenario one is near to optimal solution.

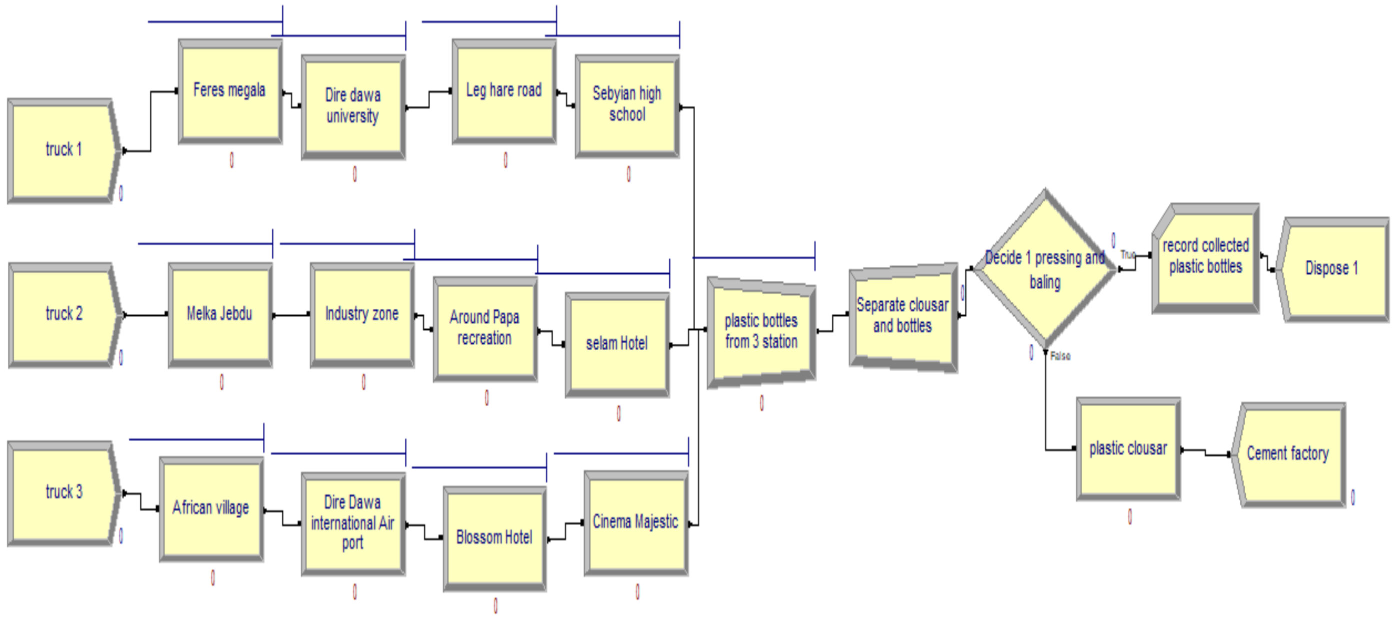


Figure 34 Arena simulation model for plastic bottle collection from Association.

8:29:49PM **Category Overview** June 12, 2018

Values Across All Replications

Plastic Bottle Reverse Logistic in Dire Dawa city

Replications: 10 Time Units: Minutes

Key Performance Indicators

System Average

Number Out 234

Plastic Bottle Reverse Logistic in Dire Dawa city

Replications: 10 Time Units: Minutes

Entity

Time

VA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
plastic bottle	216.63	16.79	186.04	248.77	44.9638	1477.39

NVA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
plastic bottle	0.00	0.00	0.00	0.00	0.00	0.00

Wait Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
plastic bottle	24.0675	5.52	16.1597	41.0682	0.00	1476.98

Transfer Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
plastic bottle	0.00	0.00	0.00	0.00	0.00	0.00

Other Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
plastic bottle	0.00	0.00	0.00	0.00	0.00	0.00

Total Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
plastic bottle	240.70	19.61	202.20	289.84	44.9638	2600.27

8:29:49PM **Category Overview** June 12, 2018

Values Across All Replications

Plastic Bottle Reverse Logistic in Dire Dawa city

Replications: 10 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
African village.Queue	0.4732	0.11	0.2291	0.7166	0.00	34.5647
Around Papa recreation.Queue	64.8042	33.83	5.3912	187.15	0.00	1476.98
Blossom Hotel.Queue	0.2894	0.16	0.00	0.5934	0.00	21.6558
Cinema Majestic.Queue	0.03357914	0.02	0.00	0.07349651	0.00	5.0636
Dire Dawa international Air port.Queue	0.1688	0.06	0.04582419	0.2959	0.00	10.2582
Dire dawa university.Queue	1.1332	0.27	0.6867	1.9508	0.00	35.0251
Feres megala.Queue	0.1129	0.11	0.00	0.4513	0.00	10.5510
Industry zone.Queue	0.00154622	0.00	0.00	0.01546218	0.00	0.4175
Leg hare road.Queue	0.4300	0.27	0.00	1.1476	0.00	17.5339
Melka Jebdu.Queue	0.5041	0.11	0.3197	0.7206	0.00	13.4052
plastic bottles from 3 station.Queue	0.00	0.00	0.00	0.00	0.00	0.00
Sebyian high school.Queue	88.2547	16.83	52.7907	127.81	0.00	1146.38
selam Hotel.Queue	0.00	0.00	0.00	0.00	0.00	0.00

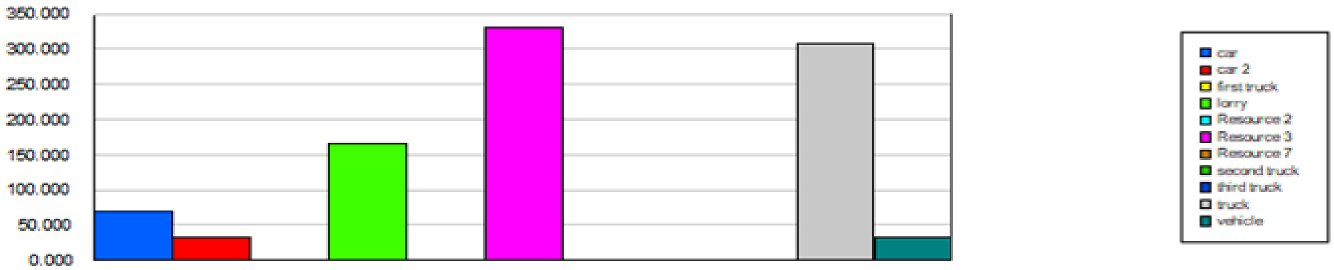
Values Across All Replications

Bottle Reverse Logistic in Dire Dawa city

Resource

Usage

Total Number Seized	Average	Half Width	Minimum Average	Maximum Average
car	68.7000	4.98	60.0000	82.0000
car 2	32.2000	2.59	27.0000	38.0000
first truck	0.00	0.00	0.00	0.00
lorry	165.20	11.17	148.00	188.00
Resource 2	0.00	0.00	0.00	0.00
Resource 3	330.60	22.50	296.00	376.00
Resource 7	0.00	0.00	0.00	0.00
second truck	0.00	0.00	0.00	0.00
third truck	0.00	0.00	0.00	0.00
truck	307.00	16.38	265.00	338.00
vehicle	31.9000	2.49	27.0000	37.0000



User Specified

Counter

Count	Average	Half Width	Minimum Average	Maximum Average
record collected plastic bottles	326900.00	14,922.84	292600.00	354200.00

Summary

The results of simulations that was shown in the table above is based on the Model that calculate the values in predictable manner. The main performance indicators, in collection plastic from the temporary storage was, transfer Time, transport cost, recourse utilization for the process and number of entities processed in the process. Within key performance indicators 234, total record plastic bottles collected 3,26900.0 which is almost similarly with manual assumption for recycling in the city. Transportation Route for truck among the destination one to other destination was based on the distance and time obtained through using **googleearth-win-pro-7.3.0.3832.exe.** of Dire Dawa city. That has been simulated based on the data available and checked the performance of transportation system during the collection of plastic bottles from all destination to pressing and baling areas. The results clearly illustrate the dramatic improvement in some performance indicators of plastic bottles reverse logistic network by using developed reverse logistics network model (Figure 36).

Simulation modeling, presented in this research, allows the user to analyze the future performance of the reverse logistic network design and to understand the complex relationship between the parties involved. The designed model calculates cycle time, transfer time; transfer cost, and resource utilization in an expected manner.

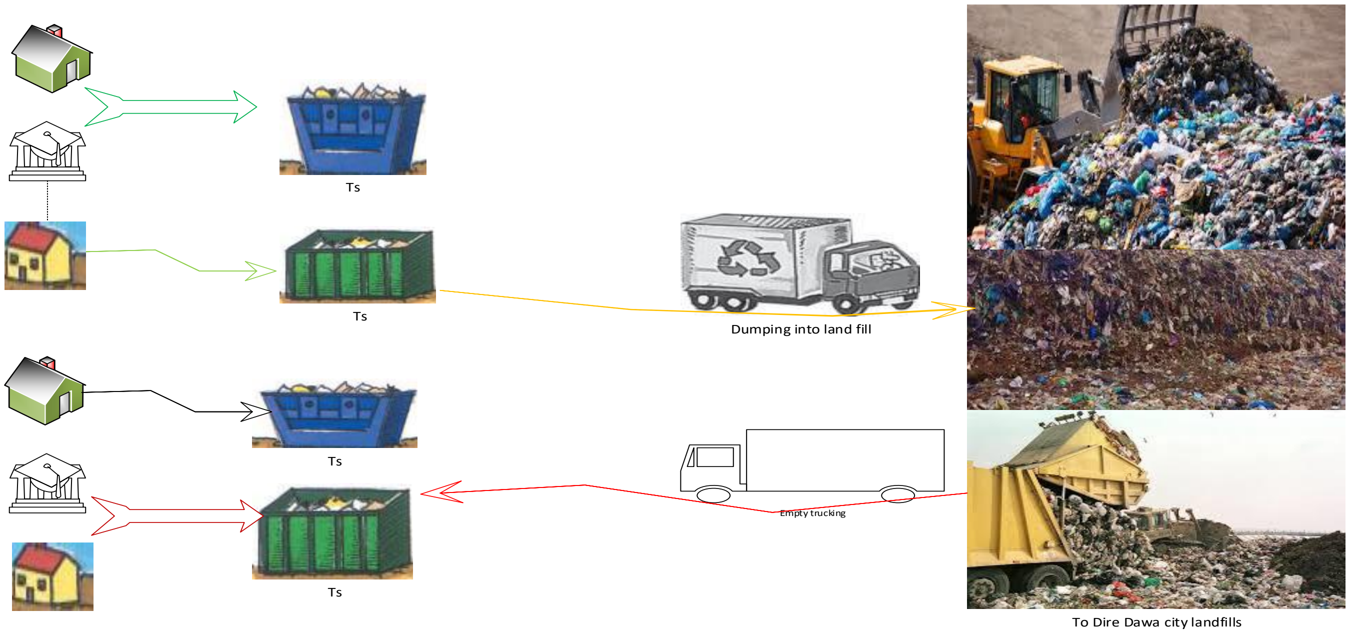


Figure 35 Existed solid waste collection network in Dire Dawa city

Proposed network for the city

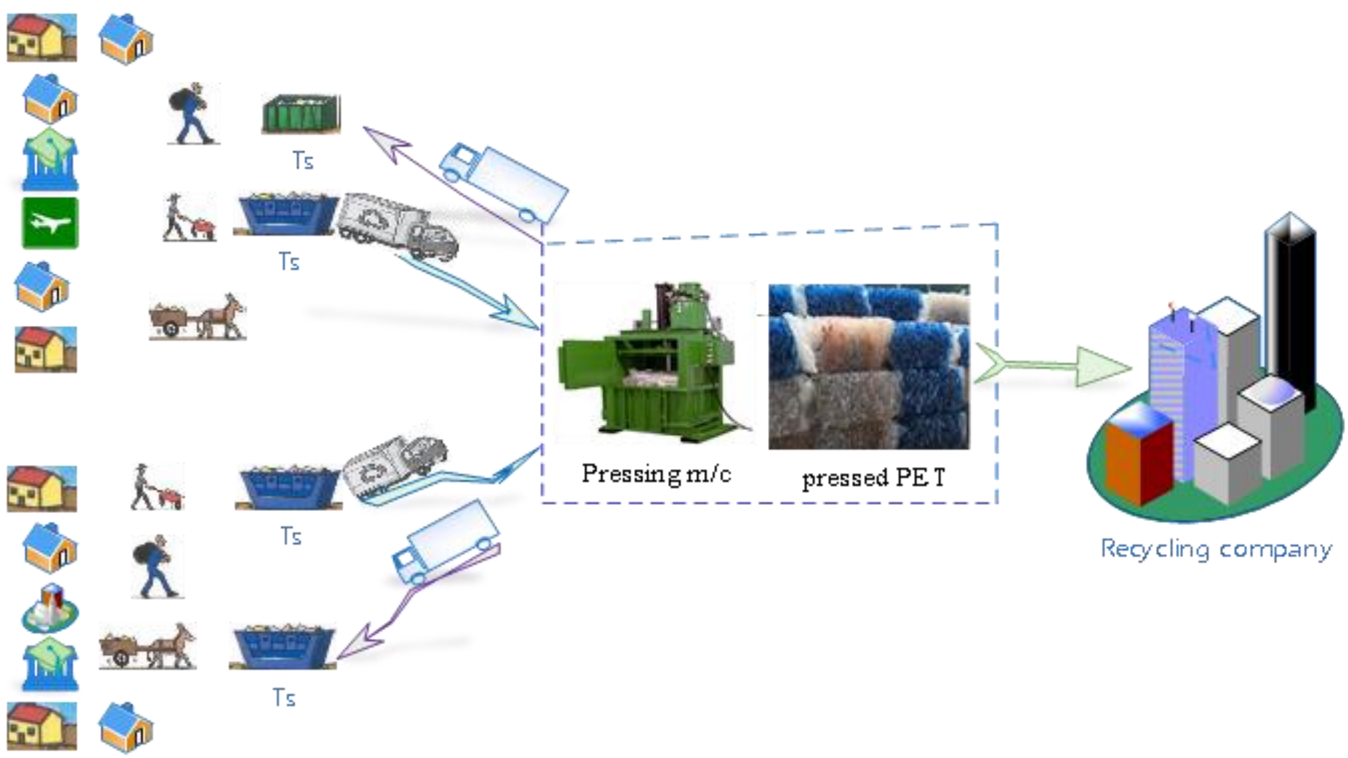


Figure 36 proposed network for collection of plastic bottle in the city.

The main source of inputs for the proposed recycling company is used plastic bottles that are collected home to home by legally organized associations or unions, higher institutions, big hotels and other places. The segregation of used plastic bottles is done by each peakers after they collect the solid waste and keep collecting it on their site and starting to sort. If association is sorting, company give payment as per the agreed price per kg and transported it to the collection site. On the other hand, the scrapped bottles and preforms are still collected from water and soft drink bottlers that are found in Dire Dawa city and further goes to the rural areas.

The bare bottles are expected to be filled in big bags so to be pressed by the pressing machine to produce bales. Each pressing machine is expected to produce 24 bales per day and then transported by truck to the recycling company for shredding process.

CHAPTER 5

Conclusion and Recommendation

5.1 Conclusion

Dire Dawa is one of the most dynamic cities in the country with its strategic geographic location between Addis Ababa and Djibouti serving as transit and terminal for import and export of commodities and services. The city also hosts several companies including nine water bottling companies. In this study, it was shown how the city can benefit both economically and environmentally from the presence of water bottling companies. However, the city is not using this opportunity as its current practice shows. Due to lack of awareness and lack of top management support, Dire Dawa city has not used its plastic bottle reverse logistic systems.

In this study, an appropriate model for plastic bottles reverse logistic system is developed. It was identified in the study that the nine-water bottling plastic bottles produce in the range of capacity between **40,000 and 75,000** bottle /day. On average, **3,585 ,893.5** plastic bottles/week have been produced and made available for potential recycling. If properly managed, as the study shows, the city can obtain an economic advantage of **$ 160,297.824** monthly from the reverse logistics of plastic bottles. To attain this economic advantage, top management plays a great role followed by creation of awareness as the interpretive structural model (ISM) result of this study showed.

5.2. Recommendation

The purpose of the thesis was to analyze and design effective reverse logistic system for plastic bottles in Dire Dawa city. To achieve the objective, researchers tried to identify practice related with plastic bottles recycling company, explored the main barriers that affect the implementation of reverse logistic system in Ethiopia, especially through taking the case study in Dire Dawa City. This research forwards suggestions and recommendations which can help to solve the existing environmental problems and ensure effective recovery of used plastic bottles in order to achieve economic advantage and further protect the environment from the adverse effects caused by plastic bottles thrown here and there in the city. So, the researcher identified the problems and forwarded possible solutions to the problems as follows: -

- In order to maximize the recovery and value of PET plastic containers in Dire Dawa city, top management should play a great role, followed by awareness creation, financial constraint, company policy and quality of the product, which is based on the interpretive structural model (ISM) result as shows in this research.
- Plastic bottle waste management should be supported by participation of people in separating plastic bottles from other organic materials at the source it self
- The community should be trained at kebele level about the usage and proper disposal system.
- Government bodies should work on organizing and supporting informal sectors which work on recycling of plastic bottles.
- To collect the used plastic bottles effectively and efficiently the separation, collection, transportation and recycling processes must be given emphasis by the different stakeholders. To do this, city sanitation and beauty Agency should Integrate with other stake holders and NGO's to develop and sustain this system
- Policies should be developed that encourage and promote informal sectors by taking into consideration the economic benefits gained from recycling of plastic bottles, in terms of the contributions towards pollution control, and conservation of natural resources.
- Private sectors who are willing to plant plastic recycling plant should be encouraged by lowering tax requirement, providing affordable space for recycling plant and marketing, allowing tax free imports of machinery and so on.

5.3. Future Research Direction

There are several issues that require further research with regard to plastic bottle Reverse logistic. Taking assumption from for recycling capacity of plastic bottle based on the data taken from the company and from agents, assign plastic bottles collection center, assigning temporary storage of plastic bottles, assign truck route for collection of plastic from all destination and specific to plastic bottle waste is one of the studies that should be done in detail. The optimization of the truck rout is the extension of the study that can be done.

Lastly, though conducting the literature review, some gaps in the area of plastic bottles reverse logistic network design and their major Barriers that affecting implementation of reverse logistic were identified and proposed as future direction. Therefore, in linking with the summarized gaps the following future direction can be given to extend the work of this study:

- The study can be extended further to other different Ethiopian Region to apply on this area, in order to be beneficiary through economic advantage.
- The network design can be applied for other case of recyclable materials with different features and within their characteristics.
- To determine the optimum truck route for collection network through different mathematical models in order to strength the sustainability of the networks.

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Appendix 1

Addis Ababa University

`Addis Ababa University Institute of Technology

School of Mechanical and Industrial Engineering

Issues: - Data Collection Questionnaire

This is an academic exercise aimed at gathering primary data towards writing a thesis work entitled **"Reverse logistic network design and analysis for plastic bottle in Dire Dawa City"** for the partial fulfilment of my M.Sc. degree program in Industrial Engineering in the school of mechanical and industrial engineering. The objective of this questionnaire is to obtain the opinion of different experts on recycling of PET/plastic bottle recycling and environmental effects on stated places.

Therefore, I would like to request you to participate in this research because I believe that your experience and your co-operation in providing honest and prompt to questionnaire is valuable for the success of the study and it would be very much appreciated. The information obtained will be used for the academic research purposes only and will not be transferred to other parties for any other purpose. And also, it is confidential that no attempt will be made to identify any individual or organizational information in any of the publications. Thus, please feel free and provide your personal opinion to each question.

Note: the information obtained here will be held in a strictly confidential manner. Neither your name nor your business company name will be used in any document based on this survey.

For any enquiry, please contact; **Researcher:** -Getu Girma

Tel; 0910398126 /0982020455

Email; getuie21@gmail.com

Advisor: Dr.-Ir. Kassahun Yimer **& Co- advisor**: -Mr. Wogene T. (PhD) candidate

***Thank you very much for your straightforward assist and* your cooperation!**

1. **Part one: -Personal Information**

Tick boxes to answer questions. Write in the space provided if it's needed

1. Your profession background……………………………………………………………

2. Your work experience in the industry

☐Less than one year ☐1-5 year's ☐ 5-10 years ☐ above 10 years

3. Please indicates your educational level; ☐ primary school ☐ high school ☐college diploma ☐ B.Sc. degree and above ☐ not educated.

4. How many persons does your company employ? ☐ 1-50 ☐ 150-100 ☐150-300 ☐300-500 ☐ above 500

2. Part two: - Recycling Activity A. (questionnaire for small and micro enterprise)

1 What kinds of materials you are collecting, mostly in Dire Dawa City?

☐ Plastic ☐ glass ☐ metals ☐paper ☐ leftover food ☐ list if others------------------------

2. Among collected materials, which one is more economically and environmentally benefited?

☐ Plastic ☐ Glass ☐ metals ☐ papers ☐left over food ☐ list if others -------------

3. Where do you collect the materials? (Tick all applicable)

☐ Streets. ☐ Landfill ☐ household ☐ some schools ☐ universities ☐ others--------------

4. Is there any collection center in Dire Dawa City? ☐ yes ☐ no

5. If your response is yes on question no.4, to whom and where do you sell or collect materials?

---

6. Are there seasonal variations in the quantity of waste collected?

☐ Yes ☐ Sometimes ☐ No

6. What recycling bins do you use while you are collecting used plastic bottle in Dire Dawa city? (Tick All Applicable)

☐ Plastic bottle bin ☐ Container bin ☐ Paper bin ☐ garbage bin ☐ none

☐ others (please state____).

Part three: - Recycling Activity for recycling company

1. Do you have any competitors that recycling of plastic bottle in our country?

☐ yes ☐ no

2. What is your daily production capacity? ---

3. Does your company remanufacturing or exports? ---

4. If you export, how much profits do your company obtain annually? ....

5. What phases/activities your company is taking to recycling the plastic bottle?

____

____

6. What benefits you obtain from recycling? (Tick All Applicable)

☐ Recycling saves energy. ☐ recycling reduces landfills. ☐ recycling preserves our resources and protects wildlife. ☐ Recycling is good for the economy. ☐ recycling helps our climate problems. ☐ Others (please state____).

7. What is your raw material? --

8. Where are the locations of your major suppliers? --

9. Do you face any problems doing this activity? If yes, what kinds of problem?

Part four: - for household

1. what type solid waste do you produce in your household? And give the response by putting a mark in the boxes which constituent with "have" and "don't have" options in front of the types of municipal solid waste which could be produced in the city.

No.		Have	Don't have

1	Diaper		
2	Animal dung		
3	Festal		
4	Chat stick and leaves		
5	Plastic bottle		
6	Paper product		
7	Food		
8	vegetable and fruit		

Part six: - <u>Questionnaire for the factories</u>

Table one information's of plastic bottling factories in Dire Dawa

No.	Name of bottling factory	Is recycling the only solution	Steps the factory taking on recycling	Possibility of adapting recycling plant	Problems that may encounter in plastic recycling	Suggestion on other means economical benefited from PET
1						
2						
3						
4						
5						
6						

Part seven: - <u>Questionnaire for city Administration</u>

Proposed kifleketema with their administrative entity, population and area.

No.	Name of kifleketema	No. kebeles	Population size	Area (hec.)	Density
1					
2					
3					
4					
5					
i6					

Estimation of post-consumer plastic bottle consumption per a day in each kifleketem

No.	Name of kifleketema	Weight of plastic bottle waste generated per day(kg)	Volume of plastic bottle waste per aday(m3)	No.of container required in each k.ketam	No. of collector required on each k.ketema	No.of collection center in each k.ketema
1						
2						
3						
4						

5						

	Barriers affecting RL in Dire Dawa city	**Very important**	**Important**	**Neutral**	**Not important**
1	lack of efficient information about RL				
2	Problems with product quality				
3	government regulation				
4	resistance to change for activities related to RL				
5	Lack of appropriate performance matrix				
6	lack of training related to RL				
7	Financial constraint				
8	lack of top management commitment				
9	lack of awareness about RL				
10	Lack of strategic planning				
11	reluctance of the support of distributer, retailer and dealers				
12	Peoples Altitude				
13	Government Regulation				

Part eight: - I<u>nterview Questionnaire</u>

1. Where are the locations of your major suppliers?

2.Where are the locations of your major distributers?

3.For how many years has your company producing products for the customer?

4. How much volume of production capacity would your company produce per a day?

5. Do you thing that, your beverage company practice revers logistic?

6. Is there any system that design for collection of plastic bottle waste in Dire Dawa City?

7. If there is a collection system, what are the main challenges that happen when collecting plastic bottle?

8. Is there any stakeholder or NGO to participate for plastic solid waste management system in Dire Dawa city?

9. In what extent, the government does use legislation on plastic waste management system in Dire Dawaa city?

Appendix 2

Transportation problem model for plastic bottles collection center: -

Truck rout for Collection center 1

```
MODEL:
SETS:
Collection_center: TRANSPORTATION_COST,
QUANTITY, LAT,LONG,D;
ENDSETS
DATA:
collection_center = CC4, CC5, CC12, CC15 ;
TRANSPORTATION_COST = 5.22, 5.52, 2.28, 3.18 ;
QUANTITY = 1400, 1400, 1400, 1400 ;
LAT = 9.37, 9.36, 9.36, 9.35 ;
LONG = 41.482, 41.481, 41.492, 41.513 ;
ENDDATA
MIN = TC;
TC = @SUM(collection_center:((LATLAT-LAT)^2 + (LONGLONG-LONG)^2)^0.5*
QUANTITY*TRANSPORTATION_COST);
END
```

A:- Truck rout for Collection center 2

```
MODEL:
SETS:
collection center: TRANSPORTATION_COST,
QUANTITY, LAT, LONG, D;
ENDSETS
DATA:
collection center = CC9, CC11, CC14, CC17;
TRANSPORTATION_COST = 2.76, 0.96, 1.62, 3.36;
QUANTITY = 1400, 1400, 1400, 1400;
LAT = 9.36, 9.34, 9.35, 9.35;
LONG = 41.512, 41.511, 41.512, 41.511;
ENDDATA
MIN = TC;
TC = @SUM(collection center:((LATLAT-LAT) ^2 + (LONGLONG-LONG) ^2) ^0.5*
QUANTITY*TRANSPORTATION_COST);

 END
```

B; -Truck rout for Collection center 2

```
collection_center: TRANSPORTATION_COST,
QUANTITY, LAT,LONG,D;
ENDSETS
DATA:
collection_center = CC1, CC7, CC10, CC16 ;
TRANSPORTATION_COST = 3.18, 3.6, 1.38, 3.42 ;
QUANTITY = 1400, 1400, 1400, 1400 ;
LAT = 9.36, 9.36, 9.35, 9.36 ;
LONG = 41.526, 41.361, 41.512, 41.522 ;
ENDDATA
MIN = TC;
TC = @SUM(collection_center:((LATLAT-LAT)^2 + (LONGLONG-
LONG)^2)^0.5*QUANTITY*TRANSPORTATION_COST);
END
```

C: - Capacity storage of temporary storage and their perspective shipment costs

```
MODEL:
! plastic bottles collection centers in dire dawa city;
SETS:
CRC/ CRC1, CRC2, CRC3/: FCOST, CAP, OPEN;
temporary_storage/ cc1, cc2, cc3, cc4, cc5, cc6, cc7, cc8, cc9, cc10, cc11,
cc12, cc13/: DEM;
ARCS( CRC, temporary_storage) : COST, VOL;
ENDSETS
DATA:
! The temporary storage, their fixed costs;
FCOST =
115598,
115598,
```

```
115598;
! Capacity;
CAP =
1400,
1400,
1400;
! collection center and their demands;
DEM =
2800,
2800,
1400,
2800,
2800,
1400,
1400,
700,
2800,
700
1400,
500,
700;
! Cost/unit shipment matrix;
COST = 0.6 .40 0.00,
0.6 1.51 0.61,
0.00 2.12 0.00,
0.50 1.30 0.10,
1.34 0.00 2.04,
1.10 0.85 1.50,
0.00 1.73 0.00,
0.00 1.79 0.00,
1.14 0.48 1.24,
2.48 0.00 1.23,
1.68 1.28 1.38,
0.32 2.69 0.45,
0.32 1.38 1.16;
ENDDATA
! The objective;
[TTL_COST] MIN = @SUM( ARCS: COST * VOL) + @SUM( CRC: FCOST * OPEN);
! The demand constraints;
@FOR( temporary_storage( J): [DEMAND]
@SUM( CRC( I): VOL( I, J)) >= DEM( J)
);
```