Addis Ababa University
Addis Ababa Institute of Technology
School of Mechanical & Industrial Engineering

Reverse Logistics Network Development for E-Waste Management in Ethiopia

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Declaration

I hereby declare that the work which is being presented in this thesis entitled: " **Reverse Logistics Network Development for E-Waste Management in Ethiopia"** is original work of my own, has not been presented for a degree of any other university and all the resource of materials used for this thesis have been duly acknowledged.

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

Dr. Ameha Mulugeta (Advisor) Date

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Abstract

This research is aiming to solve problem of managing ever increasing e-wastes particularly mobile phone wastes in Ethiopia generated in assembling companies from their production process and end users caused due to its technology advancement, shortest life span compared to other EEE and tendency to use latest model by identifying the amount of mobile phone waste in the country and factors affect implementation of reverse logistics and related issues. Due to its opposite pole economic effect, the negative in its nature of hazardous materials content that damage the environment and human and positive effect due to the presence of valuable material in it, proper management through designing circular economy driven reverse logistics networks.

The objective of designing optimum reverse logistics network and selecting appropriate business model for the enabling of the RLN in circular economy point of view, in reverse logistics a take-back practice being no longer makes the industries sustainable. For the achievement of companies for its competitiveness and countries sustainable development, implementation of circular economy effectively that is with closed concern on the two building blocks known as network design and business model is critically.

Using qualitative and quantitative data collecting through observation and interview and using questionnaire format too together with secondary document revision valuable data is collected. Literatures written in general on reverse logistics designing and factors affecting its implementation, circular economy and circular business model are reviewed selecting as much latest as possible majorly using electronic data bases.

Using the design and analysis tool together with data organizing, the result indicates that the network with 5 CC located in 5 cities with a total capacity of collecting 8,681,600 end-of-life MP is optimum but needs intervention and cooperation of government and all other stakeholders for its effectiveness on protecting human and environment in addition to solving the assembling industries problem of recycling and disposal.

Key words: *E-waste, reverse logistics design, factors, recovery, disposal, circular economy and business model.*

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Abbreviation

MIDI	Metals Industry Development Institute
E-waste	Electrical and Electronics waste
RSC	Reverse Supply Chain
RL	Reverse Logistics
RLN	Reverse Logistics Network
FDRE	Federal Democratic Republic of Ethiopia
LED	Light Emmited Diode
LCD	Liquid Cristal Desplay
CBM	Circular Business Model
BMC	Business Model Canvas
MOI	Minstry of Innovation
EPA	Environmental Protection Authorty
ESI	Ethiopian Standard Institute
WEEE	Waste Electrical Eectronics Equipment
RoHS	Ristriction of Hazardouse Substances
EEE	Electric and Electronic Equipment
ELVs	End-of-life Vehicles
PCB	Printed Circuit Board
GTP	Growth and Transformation Plan
CES	Compulsory Ethiopian Standard
CBE	Commercial Bank of Ethiopia
MILP	Mixed Integer Linear programming
OSC	Operational Collection Center

CC	Collection Center
RP	Repaired Product
RR	Request for Repair
NO	Network Optimization
GFA	Green Field Analysis
DD	Demand
DC	Distribution Center
WMP	Waste Mobile Phone
MP	Mobile Phone

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the Study

In Ethiopia as MIDI's periodic assessment and follow-up report indicates then confirmed through research, the number of industries engaged in assembling mobile are increasing with in these fifteen years that means from zero to above 20 but currently there are 6 industries assembling mobile phone with an installed capacity of more than 20,000,000 playing a role of import substitution and job creation along the supply chain especially on forward supply chain. As there is no industries that have been supplying their components or inputs and a facility where to recycle and otherwise dispose their e-waste generated during production process, mobile phone assembling companies challenged to be competitive especially in global market on compliance issue for export companies particularly. In addition they are losing opportunities of getting economic advantage from refurbishing and recycling.

Products at the hand of customer after serving its intended use with in its life time or even before due to different reasons turns to out of use but they have huge advantages when recovering them, to do so logistics systems has to be implemented for returning the used and off function mobile phones using a type of logistics called reverse logistics(Brzeszczak, 2018, Graczyk et al., 2012, Grant et al., 2016 and Trautrims, 2017).

As researchers defined, the flow of goods or things from the place where it is found or manufactured to the place or point where it is consumed fulfilling the end users requirement is the main purpose of logistics and reverse logistics consists of all these activities accomplished in reverse direction because it is a process of flow of goods or materials which are unwanted or defective due different reasons through the logistics chains to the manufacturer so that it can be recycled, reused or disposed(Govindan et al., 2015).

Return materials pass different recovery stages following reverse logistics process, as it is an effective tool for e-waste management, involve major activities along the reverse flow of materials for reuse, repair, remanufacture, reprocess, recycle otherwise dispose and since many players involve in the process, many factors will affect its effectiveness. The developed and developing countries and different industries in these countries are trying to manage their e-waste by incorporating reverse logistics in their supply chain management by recognizing its benefit(M. T. Islam & Huda, 2018; Vieira et al., 2020).

In Ethiopia there is one state owned which is established by the former Ministry of Information and Communication named Akaki Computer Refurbishing and Training Center as a pilot project with the aim of satisfying the demand of desk top computer in educational and medical centers found at regional cities by the aid of UNDP and it is currently under the supervision of FDRE Ministry of Innovation and FDRE Environmental Protection Agency. This center is currently not working. The other one is private owned recycling center which is profit oriented one focusing still on computer recycling. There are individuals participating but difficult to accept as e-waste recycler because it is dismantling some parts of the end-of-life/use electronics products like main boards and sale locally or export abroad and ignore or just sale the other like the plastic part locally without full recovery.

Many companies implement reverse logistics system and gained economic advantage in different aspect for example; Apple one of the known successful company uses and implemented RL process to make their manufacturing process environmentally friendly and to gain loyalty of their customer by letting them return old Apple phone when they want to upgrade by providing a discount on the new phone taking the old phone to the factory to use the parts which ultimately make Apple more profit and produce their product in an environmentally friendly way.

E-waste where its major source are domestic, industrial and institutions can be generated either when they finish their service life, get damaged, there is technology advancement or during production at component level. A single phone will have a minimum of 42 different components and some of them are PCB, camera, camera lens, vibrator, mice, conductor, LCD, receiver and battery. Both end-of–life/use and components of electronics equipment contains hazardous substances which have harmful effect on environment and human health needs to minimize. On the other hand due to technology advancement the life span of mobile phones are getting lower but demand on using new model and dependency of them is increasing which led to increasing of MP waste which is one types of e-waste.

An uninterrupted growth of world economy forced to exploit the scares natural resource(Thi et al., 2019). Resource scarcity as a result of rapid population, environmental regulations and economic pressure, businesses are today faced difficulties in highly competitive global markets since customers are growing more demanding in terms of social and environmental issues, government environmental standards to be taken into account by businesses in order to be accountable for their end-of-life products and the waste electrical and electronics equipment (WEEE) directive focuses on reducing waste disposal and promotes the effective use of resources by reusing, recycling, and refurbishing. In addition, restriction of hazardous substances (RoHS) are implemented in developed countries(European Union) with the objective of limiting the use of specified hazardous elements present in EEE (Thi et al. 2019). To conserve and not relay on this scares recourses, reusing materials become central issue and this is because of the price of products to produce using recycling material reduced for many reasons, mainly energy utilization for reprocessing, consumables relief, its volume and the gathering cost of reusable material due to proximity to the society(Söderholm & Ekvall, 2020) and (Grigoropoulos et al., 2021).

Electric and electronics equipment where their functions are dependent on the supply of electric current and electromagnetic field covers variety of types like "large household appliances, information technology and telecommunication, medical devices, lighting equipment, monitoring and control instruments, automatic dispensers, and consumer electronics, such as electrical and electronic tools, toys, leisure and sports equipment, and mobile phones to computers. Wastes comes from end-of-life/use of these electric and electronics products is known as e-waste(Ilankoon et al., 2018). Component wastes of electric and electronic equipment (EEE), such as batteries, electric cables from end-of-life vehicles (ELVs), printed circuit boards (PCBs), plastic casings, cathode-ray tubes (CRTs), activated glass and lead capacitors are also classified as e-waste Chen et al., 2015b, Lambert et al., 2015," (Iqbal et al., 2015). Likewise e-wastes generated from the production or assembling process of the electric and electronics products and equipment are industrial e-waste.

In this industry4 revolution or digital era together with the technology advancement of electronic industries and increasing tendency of using electronic equipment especially the information and telecommunication devices results in the production of e-waste in large amount globally (Gao et al., 2019). These products like mobile, are useful for different purpose for our daily life are globally multiplying five times faster than human with an increase rate of 5 to 10 % and reaches from zero to 7.2 billion with in three decades(Masud et al., 2019).

The fastest-growing categories of waste for instance, 80% of mobile phones are changed every two years results in a lot of discarded good, differs from ordinary systems of RSC or RL rather it needs a distinct e-waste RSC in that it has some unique qualities and traits, such as a short product lifecycle and a significant volume of precious and dangerous materials contained(Thi et al., 2019.). The RSC for e-waste has intricate procedures that start with e-waste disposal. The amount, quality, and timing of returned goods are unknown in this dynamic system(Iqbal et al., 2015).

Goods or materials which are unwanted or defective due different reasons through the logistics chains to the manufacturer so that it can be recycled, reused or disposed are reverse logistics(M. T. Islam & Huda, 2018)(Girma et al., 2018). It is a management as well as engineering process in the perspective of material characteristics and processing consisting all the logistics activities in backward flow of materials in order to give value returning to the place where they are reprocessed and make ready to use or otherwise disposed (Brzeszczak, 2018), (Graczyk et al., 2012), Govindan et al., 2015, Grant et al., 2016 and Trautrims, 2017).

Products under the category of EEE produced by electrical and electronics industries play a role in generating these e-waste(Ilankoon et al., 2018). This e-waste unlike other waste has a potential to give value at a maximum of 96% of it and besides the valuable material found there, is also contains hazardous elements which can affect the environment and human health(Singh et al., 2018). Effective e-waste management covers collection, handling, processing (recycling and recovering) and disposal but managing this e-waste in Ethiopia were not effective and especially system in managing waste MP have not yet practiced. So to solve this problem the major factors out of the different are identification of collection center with optimal number and capacity, the research focuses and done through designed optimum reverse logistics network which helps for better implementation of mobile phone waste management and can be used for other type of e-waste as well.

As a country, Ethiopia signed treaties regarding environment protection, national proclamation and regulation also there in relation to e-waste management and disposal, the pilot project for desk top computer refurbish center establishment these all show us that there is an interest and trial but needs to strengthen with such type of tool for better implementation.

There are about 37 electrical and electronics industries in Ethiopia currently and 13 of them are electrical producing cables and transformer and 24 of the them are producing television, mobile, LED lamp, reciever, refrigrator, solar generator and oven. Out of the total, 6 industries are mobile assembling(*Source: MIDI)*. Through the research focused and conducted together with perivious exposure on the industry which is lately accepted by the reseach, mobile assembling industries are the major contributors in generating e-waste is hazardouse too. So, for their sustainable e-waste management through the implementation of optimized reverse logistics which will impact on the sustainability of the industry and ulimatly the environment and human as well.

Thus for better performance and sustainable industrial e-waste management system to implement and ultimately to give response for the environment well developed and optimized reverse logistics network and attractive business model needs to be modeled through identifying the major factor/s affecting the effective implementation of revere logistics system and select optimum number of collection centers with optimum transportation cost where the end-of-life MP phones are collected and transported to the recycled center respectively.

So, generally why the research area focus on mobile:

- Shortest life span and fastest technology adoptability.
- Due to the presence of toxic material especially in battery of the mobile phone.
- Presence of valuable materials its largest share compared to its size.
- Its characteristic in the aspects of usability, one refrigerator, one TV most of the time, one washing machine or one oven for a house holed but there may be seven mobile phone in a household with seven family.
- Easily disposability nature due to its smaller size and mobility with user’s movement.

1.2 Problem Statement

Increasing number of mobile phone users and absence of data on the amount of waste mobile phones

Mobile phone user worldwide count above 7billion and its waste reach above 5.27 billion as of April, 2021 and in Africa half of its population is mobile voice subscriber. In Ethiopia data from Ethio Telecom shows that mobile voice subscribers reaches to 66.8 million at end of 2022, at an average of 15% growth rate in the past ten years. This is due to the increasing number of MP assembling company which were none and currently reached to 6 with a capacity of more than 20,000,000 pieces annually led to a large number of MP can produce and enter in to the market in addition to the imported one.

The country service digitalization policy in financial, medical, marketing, educational, agricultural and trade mainly influencing and becoming motivator to people to use MP. The country like Ethiopia which is the second largest populated African country with a population, as per World Bank and UNFP, of more than 120 million in 2022 with 57% of its population in the age of 15 to 65 and the lowering of EEE life span particularly mobile phones results large number of waste mobile phones to be generated in the country and there is no research conducted in the amount or generation of its waste.

As mobile phone contains hazardous material like cadmium and bromine which can harm the environment and human as a study mentioned 600,000lts of water can be polluted with a single mobile phone specially a battery inspite of the recyclable and valuable materials like gold, copper and aluminum present in it, it can imagine that how difficult it is being reluctant to the end-of-life/use of mobile phones to be managed properly.

It is mobile phones one of the WEEE under the small telecommunication equipment category grows at increasing rate of above 51 % in 2019 compared to 2016 according to Global E-waste 2020. This increasing is mainly due to replacement of end-of-use and even in-use MP due to droppings of their life span on average of two years in developed country but three in developing countries which is directly impact generation of obsolete MP. In addition, the component level e-waste generated during assembling process has to be known and managed properly (Söderholm & Ekvall, 2020; Thavalingam & Karunasena, 2016 & ethio telecom report March 1, 2022).

Absence of mobile phone recycling center and disposal site

The country has a history of introducing mobile voice phone communication for the people before 20 years and started manufacturing locally in 2011, the number of subscribers is increasing from nearly 400,000 on 2004/5 to 66.8 million on 2022. So, since then the component level e-waste and the end-of-life MP has been generated. The 15% average rate of increase in number of subscriptions lets us that significant amount of end-of-life as well as component waste from assembling process have been generated. The hazardous elements found in MP cause damage on human as well as environment, needs properly collected, recycled and disposed. But there is no recycling company engaged in recapturing values of these wastes to usable form to protect environmental and human damage and to gain economic benefit due to valuable materials present in it as well. Even there are no disposal sites where assembling companies dispose their hazardous waste and facing challenges on their sustainability.

The only existing government owned e-waste recycling known as Ethiopian Computer Refurbishing and Training Center established with over 54m birr capital around Akaki, under Akaki Kality Sub City in Addis Ababa with annual capacity of 100,000 computers to refurbish were expected to refurbish end-of-use/life computer by importing from abroad and collecting from government institution to provide for primary school and health institutions but it couldn’t be effective.

Moreover, Ethiopia singed different treaties regarding environment protection, on importing into and controlling of trans-boundary movement and management of hazardous wastes within the country and continent Africa specifically to prevent transfer of hazardous waste from developed to less developed countries intending to minimize the rate and toxicity of wastes generated to ensure environmentally sound management as closely as possible to the source of generation, and to assist less developed countries in environmentally sound management of the hazardous and other wastes they generate. But they are not even collected or disposed.

Absence of reverse logistics network and waste mobile phone collection centers

In the country collection centers and mechanism of collection for e-waste in general and mobile phone waste in particular are not yet implemented separately rather solid wastes which contain any type have been collected and undefined but expected to be large number of hazardous parts like end-of-life mobile phone battery, mice, pin, speaker, screen are thrown with other solid waste/municipal wastes.

Let alone the least developed country like Ethiopia, the developing as well as developed countries implementation of reverse logistics for e waste management is at its infant stage(Guarneri, Camara e Silva, et al., 2020a). Ethiopian MP assembling industries most of them are producing both feature and smart phones of different model with an average of 46 components under SKD and CKD standard based on the level of assembling to produce a single phone. During assembling process some of these components will get complete failure due to different reasons after detecting the defect and correcting them in the production line with respected technicians following quality control process become e-waste.

Assembling industries on after sells service process reuse some of the functional components from failed product and discard the failed parts and due to the absence of collection and recycling discarded MP related e-wastes even batteries will throw with other solid waste. These component level e-waste and end-of- life/use needs properly managed to safe guard the environment and human because they can significantly contribute considerable amount of e-waste generation. But there is no effective e-waste logistics as well as reverse logistics network designed and implemented for industrial e-waste as well as used mobile phones management.

Due to its economic advantage together with environmental concern industries are turning their face in implementation of RL(Ilankoon et al., 2018; Kitila & Woldemikael, 2021; Masud et al., 2019; Nnorom & Osibanjo, 2008; Regassa et al., 2011; Srivastava & Pathak, 2019). Incentive for collectors and remanufacturers of e-waste and sellers and even users of the recycled products as well as users who hold on their end-of-life/use mobile phones in the form of subsidy will help the e-waste management system along the forward and backward flow but in Ethiopia there is no incentive scheme implemented that motivate owner of e-waste, recyclers and recycled product sellers and users(Wang et al., 2019).

1.3 Research Questions

The research questions that have been raised and expected to answer were;

1. What is the current situation of mobile phone assembling industries e-waste and end-of-life mobile phone waste management?
2. Where to locate and how many number of collection centers would be needed to collect end-of life/use mobile phones?
3. What type of business model will be appropriate to sustain the reverse logistics of the e-waste management?

1.4 Objectives

1.4.1 General Objective

The general objective of the study were to identify the factors that affect the implementation of reverse logistics system in Ethiopia on e-waste management practice in mobile phone sector and develop reverse logistics network with selection of appropriate business model.

1.4.2 Specific Objectives

The specific objects to be achieved for the ultimate achievements of the general objective were;

1. To assess and understand the current Ethiopian mobile phone assembling industries e-waste and end-of-life mobile phone waste management practice.
2. To analyze the existing barriers and drivers affecting implementation of reverse logistics.
3. To estimate the amount e-waste generated from MP assembling industries e-waste as well as end-of-life MP.
4. To develop the network then selects the optimal network.
5. Identity appropriate business model which support the implementation of the network.

1.5 Scope of the Study

The intent of the research is to assess the current situation of e-waste management practice and identify the factors which affect the reverse logistics on the industrial e-waste management and come up with reverse logistics network development. But the scope is on MPWM on assembling industries and users side since there is a gap on this product category especially today's world where people's towards information interconnection is increasing due to digitalization, fast adoption of mobile phone technology which pulls MP users to have advanced or new technology changing and this resulting in life span of the product becoming lower which aggregately impact on increasing end-of-life/use mobile phones. In addition, mobile phone by its nature contains both valuable and hazardous material which needs to properly manage.

1.6 Significant of the Study

The significance of this research, as waste mobile phone in particular contain hazardous material which causes danger to both the environment where we are living in and human health,

- Shows the stallholders mobile phone is one of potential sources of e-waste in the country and needs attention.
- Indicate expected amount of mobile phone related e-waste in Ethiopia generated from mobile phone users and assembling companies.
- Gives direction on why the off functional refurbish center needs to be functional.
- Shows approaches that in what way of cooperation between stakeholders would come together for better MPWM to solve the problem of the MP assembling industries and protect the environment and society.

1.7 Limitation of the Study

The limitation in this research were lack of numerical data related to costing and pricing as there is no past experience in the same practice of recovering mobile industry component level e-waste and end-of-life mobile phone. But data in similar area and studies of other country supports for appropriate utilization to reach to the required level and finding of the research.

1.8 Organization of the Study

This research starts by introduction why revers logistics is an issue and what makes it critical in regarding e-waste particularly mobile phone waste management together with its objectives. In addition research questions that has to be answered to resolve the stated problems. The second section is about reviewing studies conducted in similar area of the research accessing different electronic data bases. Here literatures written on reverse logistics in general and circular economy, sustainability, resource, recycling, refurbishing is reviewed.

The third section is methodology which is concerned about identifying the research design, type of data and data sources, identifying the data collection and analyzing methods. The fourth chapter is about discussions and analysis on the current e-waste particularly mobile phone waste management practice in Ethiopia and identifying factors affecting most then reverse logistics network development for mobile phone waste management and finally adopting reverse logistics business model for the effective implementation and its sustainability. Finally the sixth section it about conclusions, recommendations and feature research work is reflected.

CHAPTER TWO

2. LITRATURE REVIEW

2.1 Reverse Logistics and Circular Economy

2.1.1 Reverse Logistics

In a broader view point according to Anca, (2019), supply chain management is stated as "a set of synchronized decisions and activities" used to integrate the suppliers, manufacturers, warehouses, all involved transporters, retailers, and the final customers in a more efficient manner, all of which help to ensure that the right product or service will be available and distributed at the right quantities, at the right prices, to the right locations, in the right condition, and at the right time, so as to achieve a long lasting competitive edge.

Logistics, one of a process in supply chain, stated by Martin (2011) as, "the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organization and its marketing channels" with an eye toward both present and future actions, and this through cost-effective order fulfillment. From this total systems viewpoint, logistics management means concerning on satisfying the needs of customers “through the coordination of the materials and information flows that extend from the marketplace, through the firm and its operations and beyond that to suppliers”. It is obvious that a very different orientation than what is typically found in conventional companies is necessary to achieve this extensive integration of the company.

Reverse logistics, category of customer return, undergo process for recovery of product values through collection, inspection and sorting, reprocessing and finally in redistribution of end-of-use and end-of-life products out of the different return management in a supply chain. The reprocessing level difference as per the level of return products(Ugandan, 2014).

It is a management as well as engineering process consisting of all the logistics activities in backward flow of materials in order to give value returning to the place where they are reprocessed and make ready to use or otherwise disposed. Reverse logistics, unlike the forward logistics in that its main purpose of transportation of goods or things from the place where it is found or manufactured to the place or point where it is consumed fulfilling the end users requirement, consists of all these activities accomplished in reverse direction because it is engaged in transporting of materials which are unwanted or defective due different reasons through the logistics chains to the manufacturer so that it can be repaired, reused, recycled, or disposed (Brzeszczak, 2018, Graczyk et al., 2012, Govindan et al., 2015, Grant et al., 2016 and Trautrims, 2017).

According to Vieira et al.(2020). Through the refurbishment, reuse, and recycling processes, reverse logistics has emerged as a method of disposal and a conscious way to use products at the end of their useful life and it is mostly in non-industrial nations.

Guide and Van Wassenhove,(2019) also shows the important role of revers logistics in the reverse flow of closed-loop supply chains focusing on product return and value recovery by reusing the whole product or its parts for the intention of value capturing otherwise disposal through the process take back or recollect goods from their final destination. Because holistically reverse logistics takes concern on managing, processing, reducing, and disposing of hazardous or nonhazardous waste from production, packaging and used products including the processes of reverse distribution.

Bouzon et al.(2016) similarly discuses about reverse logistics that; it is the joint responsibility of producers and consumers to minimize waste generation through its known process of reusing, remanufacturing, recycle and safe disposal of end-of live and end-of-use products in-tenting to improve the rejuvenate and recovery capacity of the planet, contributing on the issue of sustainability and circular economy. So the growing importance of reverse logistics by producers and their stakeholders worldwide is due to resource depletion, environmental concerns, increasing costs of landfilling and substantial return policies of retailers.

According to El Barky, (2016); Sobhy ; Barky (2016) & El Barky (2016), through the product recovery strategies, mainly they are four as the latter study stated, value can be recaptured from end-of-life and/or end-of use products using proper product recovery. This has been done through five steps. These are product acquisition, transportation and warehousing, inspection and disposition, recovery and distribution and sales. Since transportation involves in between the stages and within a stage, needs attention and optimized to attain effective implementation of RL.

2.1.1.1 The product recovery process of reverse logistics

The product recovery process as many scholars mention and for instance El Barky (2016)

a) Repair

The return products at their product level need only some parte to be changed or replaced just restoring to the condition of working.

b) Refurbishing

One of the reverse logistics activities where the return products at their module level needs to repaired and replaced for upgrading its function through testing the critical modules to meet the required and specified quality level.

c) Remanufacturing

The returned products at their parts level and needs testing the all modules and parts to comply with the required new product using good status used and new parts and modules and upgrading at their maximum potential.

d) Recycling

At this material level, the materials are used for producing new parts and high quality requirements are needed to comply with the original parts level.

e) Disposal

Here at its material, parts and module level which cannot be go through one of the above process is oblige to dispose properly.

2.1.1.2 Factors affecting implementation of reverse logistics on electronic industries

Reverse logistics, an effective tool for e-waste management, involve major activities along the reverse flow of materials for reuse, repair, remanufacture, reprocess, recycle otherwise dispose and since many players involve along these processes, many factors will raise and affect its implementation. The developed and some of the developing countries and industries in these countries are managing their e-waste by incorporating reverse logistics system in their supply chain management and every company its own supply chain with their specific policy as a competitive advantage for their competitiveness(M. T. Islam & Huda, 2018; Vieira et al., 2020)

These factors could be drivers which motivate or force company to implement reverse logistics, barriers are those factors which hinder from implementing and enables are those which supports the implementation.

A) Drivers

Due to regulation on environmental issue being strong together with competitiveness and ever increasing e-waste generation electronic companies and government of a country tends to be interested in practicing on implementation of revere logistics for e-waste recycling.

According to Thi et al. (2019)to control the amount of electronic products disposal, reducing, reusing, recycling, recovering, redesign and remanufacturing activities known to be the 6R concept have been undertaken by companies with the intention of minimizing activities that have no contribution on adding value for e-waste management to improve recovery implementation to protect the environment. Financial benefit to the company; mainly through cost reduction, product usages through material recovery, growth of market share, public reputation enhancement and competitive advantage is the driver that benefit and motivate for implementation of revere logistics.

Similarly, Guarnieri, Camara e Silva, et al.(2020) mentioned economic, governmental, corporate responsibility, technological and logistics are factors which derives to the implementation of reverse logistics system; related to costs of production and environmental and material usage; environmental focused policy and legislation; product design through technology advancement on circularity; and modality for reverse flow respectively are concerns goes with each factors.

As Lal et al. (2023) explained the recyclability and valuable material present in it and by the concept of circular economy adoption through reverse logistics process for recovering the valuable material which are precious metals gives benefit to the individuals, industries and a country as well become opportunity which can play a role for motivating companies to implement RL.

B) Barriers

The amount of e-waste recovered globally becomes very few as compare to its generation. This is mainly because of many barriers that affect the implementation of reverse logistics.

Different researches agreed and mentioned that reverse logistics as it is a strategic tool for environmental and economic sustainability have a relation with many stakeholders needs coordination and collaboration with these bodies makes it complex and affected by different factors. Most of the external factors for instants; government regulations in general and environmental regulation specifically, public awareness, economic elements, incentives and customer demands together with the internal factors which are managerial and technical skills, technology, financial issues are barriers to its implementation.

Waqas et al.(2018)explain about barriers, that to support producers minimize pollution by decreasing the burden caused by load of end-of life products on the environment especially e-wastes as it contains hazardous materials, through disposal can be solved by adopting reverse logistics. High transportation and storage cost, high processing cost, lack of integrated corporate supply chain strategies to wards revers logistics, poor waste management, lack of interest by top management on activities and functional priority on revers logistics, low awareness about reverse logistics, lack of time commitment are barriers that cause organization decide to or resist from implementation of reverse logistics. Off-course, their degree of severity varies from company to company. Even within a company, the same barrier might need different treatment methods and may vary in the priority and importance given due to a variation based on a given organizational resources, strategies, and capabilities.

As Vrat et al.(2017) listed sixteen factors and discussed out, lack of sufficient information, poor infrastructure, lack of accepting extended producer responsibility, legal issues, limited capacity of government agencies to deal with e-waste, lack of technology, dominance of unorganized sector, funding and sustainability issues, problem of cost bearing on recyclers only for e-waste recycling process, lack of awareness, consumer's irresponsible behavior, lack of incentives, lack of research, illegal imports of e-waste, products of untraceable source (free riders or orphan products), lack of coordination among various authorities. Similarly, Guarnieri et al.(2020) categorized the barriers in to seven and these are financial/economics, environmental, market related, legal, policy related, management, knowledge related and technical and technological related which affect the implementation of reverse logistics system. Bouzon et al.(2016) identified and summarized in seven categories of 36 barriers that have an effect on the implementation of revers logistics and selected the six categories of 26 barriers through prioritizing the categories as well as the barriers under each category which have sound effect.

According to(Jayant & Singh, 2018) revers logistics recovery process themselves; these are sorting, transporting and handling of product return are challenges due to higher level of uncertainty with regard to quality, quantity and timing of end-of-use and or end-of life products.

C) Enablers for reverse logistics system implementation

As Lal et al. (2023) explained the recyclability and valuable material present in it and by the concept of circular economy adoption through reverse logistics process for recovering the valuable material which are precious metals gives benefit to the individuals, industries and a country as well become opportunity.

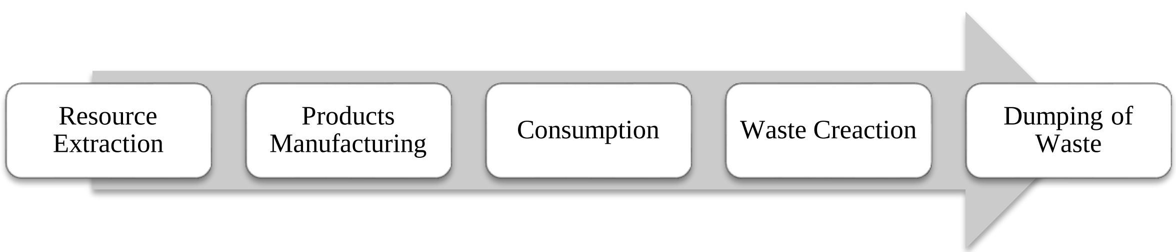
Presence of legislation together with government's commitment, availability of financial aid, society awareness, technology capability and required skill are enables for implementation of revere logistics system.

2.1.2 Circular Economy

The limited resource due to take-make-dispose approach in many years practice led to problem of sustainability keeping productive or profitable in an industry which consume raw material as an input for producing product of different type which then push the emerging issue on demand of ever using resources in circular economy thinking (Bocken et al., 2019; T. Islam & Iyer-raniga, 2022).

Similarly, linear model as explained by Makarova et al.(2021), is the basic for production of goods undergone by extracting natural resources and turning in to products that can be used for limited time and lasting landfill. Despite some of them are recycled caused gradually unsustainable for businesses and rises the issue of resource depletion, climate change and negative impact on the environment which then become factors for raising question of responsibility to future generation on preservation of life ultimately the emerging idea of circular economy.

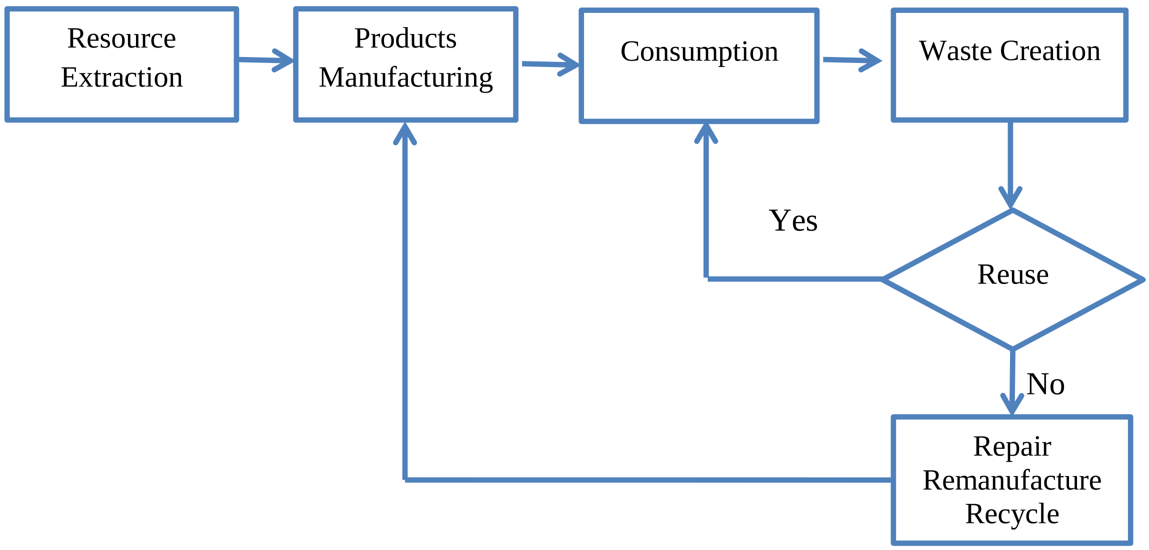
In addition, Upadhayay, (2018)explained the focus of circular economy is to prolong the life cycle of end-of life and end-of use products by increasing its efficient and effective utilization to get maximum value out it through changing alternative resource, minimizing waste attaining a close loop in the industrial ecosystem on philosophy of reuse, recycle, repair and remanufacture through the use of reverse logistics, innovation, redesign and collaborative ecosystem to efficiently manage the resource which is against the traditional extract-produce-dispose approach to restorative and regenerative approach.



Source: Upadhayay, (2018)"Transition from linear to circular economy".

Figure 2-1 Linear economy flow diagram

As it shows on the above figure, the linear economy focus is on the transformation of materials to satisfy the demand frothier consumption and don not bother about the waste and recycling it but time goes after issue of material/resource scarcity, environmental becoming uncomfortable due to pollution caused by landfill through dumping leads thinking on reusing material and protecting environments and come up with circularity idea.



Source: Upadhayay, (2018)”Transition from linear to circular economy”.

Figure 2-2 Circular economy flow diagram

On the other hand T. Islam & Iyer-raniga(2022); Lewandowski(2016) explained the building blocks of circular economy where, the former mentioned the four fundamental one but the later the six main building blocks and the decision factors that influence the implementation of circular economy. Global reverse network or revere logistics and business model are the two found out of the explained building blocks in both scholars study. Clear understanding and communication is needed between these building blocks and the factors for effective implementation.

2.1.3 Reverse Logistics and Circular Economy relation ship

Reverse logistics and circular economy both engaged in similar activities where reverse logistics dedicated on bringing the return products to the place where it will get value through its major activities of direct reuse, repairing, refurbishing, remanufacturing, cannibalization and recycling through stages of collection, sorting and inspecting and recovery process then finally dispose, but circular economy performing maintaining, collecting, repairing, refurbishing, remanufacturing, and recycling thought its principle of the 3R(reduce, reuse and recycle) recovery strategy (El Barky 2016 &Ripanti et al., (2016).

Ripanti et al., (2016)The goal of reverse logistics is to create an effective process for organizing, carrying out and managing the flow of material for the purpose of recapturing the benefits of proper recycling and disposal. Whereas circular economy, to keep products at their ultimate utility and value in the circulation.

According to Govindan & Soleimani,(2016) revers logistics, concepts of circular economy, is one of the tools through the focus of reducing utilization of natural resources giving priority to reusing products and materials. Ripanti et al., (2016)It has a basic role in the development of circular economy for implementation of its 3R principles mainly keeping the material flow in the circulation at a lowest cost. Circular economy based on reverse logistics can provide positive impacts for instance on developing a cycle of economy and contributing on reverse logistics efficiency.

Ripanti et al., (2016) shows us that how circular economy and reverse logistic integrate in return product designed for refurbish process that is one of reverse logistics activity. By adopting the circular economy principle over reverse logistics operation, to maintain the circularity of products minimize waste.

2.2 Circular Economy Driven Reverse Logistics Business Model

According to T. Islam & Iyer-raniga, (2022); Lewandowski, (2016), business model is one of the building block of circular economy and organization or company has a business model which defines how can create, deliver and capture value. A business model which describes value creating, delivering and capturing strategy of an organization in circular economy is circular business model. Similar to circular economy, one of the most important components of CBM is reverse supply chain.

2.2.1 Circular Economy Domain on business model perspective

Based on T. Islam & Iyer-raniga, (2022), There are two distinct domains from the standpoint of business models:

1. Sustainable business model and
2. The circular business model.

As the reverse logistics activity in its supply chain route involves different stakeholders, here also in circular business model/ sustainable business model involve number of participants to be managed makes it participatory in their respective responsibility along the creation or recapturing of values in the long term categories in sustainable business model domain. But, a model focus on the design of product and service for reducing resource utilization there by generation of waste and environmental pollution due to emission linkage of an organizational system is categorized in to CBM.

2.2.2 Category of circular business model

Based on the strategy used for recapturing the value of the product concerning on circularity, the circular business model are categorize in to three. These are;

1. The Gap Exploiter model
   The central focus of this model is exploiting the residual value in unused products by employing one of the reverse logistics as well as the circular economy activity that is repair strategies. Here the gap on the product to give the intended function is filled with repairing so that it returns to function at most to the level of original.
2. Access model
   This model focus is extending the useful life time of products using remanufacturing with the aid of retained ownership. Remanufacturing make the product new and gives a potential of utilizing it in a better performance. And the third model is Sharing platform.

2.2.3 Circular business model frameworks

The building block distinguished from a more recognized and applied framework of a business model and conceptualized as the business model canvas (BMC) is:

(1) Customer segments that an organization serves (2) Value propositions that seek to solve customers' problems and satisfy their needs (3) Channels which an organization uses to deliver,

communicate and sell value propositions (4) Customer relationships which an organization builds and maintains with each customer segment (5) Revenue streams resulting from value propositions successfully offered to customers (6) Key resources as the assets required to offer and deliver the aforementioned elements (7) Key activities which are performed to offered and deliver the aforementioned elements (8) Key partnerships being a network of suppliers and partners that support the business model execution by providing some resources and performing some activities and (9) Cost structure comprising all the costs incurred when operating a business model.

2.2.4 Factors affecting CBM adoption

Circular business model is one of the enabler for the implementation of circular economy and circular economy as mentioned is the strategic model there are factors that affect the adoption of this model are assessed by different scholars but referenced by T. Islam & Iyer-raniga, (2022) are;

1. Human resource, where trained and skilled.
2. Political system and legislation.
3. Information communication and data management.
4. Business risk.

Mostly they are general and can affect any other business model too. But leadership, collaboration and motivation are enablers of the model to be adopted. So the research has been given focus and attention on these factors and enables to be effective in the implementation of reverse logistics system.

2.3 Reverse Logistics towards Industrial E-waste management

2.3.1 E-waste generation and growth

As the research focus is the mobile assembling industrial waste; capacitors, circuit boards, mobile battery, microphone waste and speaker and end-of use and/or end-of life mobile phone are some of components level wastes generated during production and repair on their after sales service center where as e-waste from the later will be generated due to damage, technology advancement, customer demand and requirement shift and the like.

It is definite that as the tendency of using electronic devices and being dependent on them has an impact on demand which increases the inflow of electronics products to the market there by the capacity utilization or industries production to increase. As e-waste is end-of life and/or end-of use electronics and electrical products and their failed component and parts, an increase in using them led to increase in generation of e-waste which is originated from industries producing them.

As Forti et al.(2020); Kitila & Woldemikael (2021); Srivastava & Pathak(2019) and Ilankoon et al.(2018) the three primary sources of e-wastes are consumers, industries, and institutional. It is internationally accepted that all scholars have been taken in to attention and agreed upon the increasing rate of e-waste generation and it is not only increasing but at a fastest rate due to the source where these e-waste has been generated. The electrical and electronics equipment when they reach at end-of use and end-of life due damage, finish service life, lack of proper maintenance, technology advancement which causes lower life time but cheaper and lighter become e-waste. It reaches at 53.4 Mt of e-waste generated in 2019 and also estimated to increase the rate(Forti et al., 2020; Widmer et al., 2005). The major contributor of e-waste globally shows developed country but in near future the developing and under developed country also will face the same problem due to urbanization and digitalization and aggressively joining on the information communication system.

From the total 53.6 Mt of the global e-waste generated in 2019 Africa as a continent generate 2.9Mt with per capita of 2.5kg. Next to the six countries Egypt, Nigeria, South Africa, Algeria, Angola and Morocco, Ethiopia is the country seventh in the list which generates highest e-waste of 55.2kg.

According to global e-waste monitory, the growth of e-waste generation in 2019 in relation to 2016 increased by 11.2% and estimated to grow by 39.4% by the year 2030. The individual contribution also increase and the per capita of e-waste generation in 2019 increase by 7.35% and is expected to grow to 23.28%. This tells us that e-waste could continue being the global concern and needs to give attention more (Forti et al.2020)"The Global E-waste Monitor 2020,Quantities, flows, and the circular economy potential".

According to Thavalingam & Karunasena, (2016) justification, mobile phone characterized in small size but large in number can cause considerable impact in damaging the environment and human health since the higher adoption rate results in shorter life span of 1 to 2 years compared to other EEE like computer and printer more than 6 years, television more than 7 years, refrigerators more than 8 years and because of the users demand to have latest technology which then led to create larger number of obsolescent finally ends in generation of significant amount of e-waste(John et al., 2018).

2.3.2 E-waste category and its management system

According to Thi et al.(2019.) e-waste as its source is any type of electrical and electronics products and components which are no longer usable by its user and discarded for further recovery. Screen and monitors, large and small devices, small IT and telecommunication equipment, temperature exchange devise and lamps are its six major categories. Based on their category the material used as they contain hazardous, and the functions given are different so that their harmfulness on the environment and human health will depend on the manner they are managed.

As Iqbal et al.(2015) mentioned, electric and electronics equipment where their functions are dependent on the supply of electric current and electromagnetic field covers variety of types like "large household appliances, information technology and telecommunication, medical devices, lighting equipment, monitoring and control instruments, automatic dispensers, and consumer electronics, such as electrical and electronic tools, toys, leisure and sports equipment, and mobile phones to computers. Components of electric and electronic equipment (EEE), such as batteries, electric cables from end-of-life vehicles (ELVs), printed circuit boards (PCBs), plastic casings, cathode-ray tubes (CRTs), activated glass, and lead capacitors are also classified as e-waste".

According to Söderholm & Ekvall, (2020) and (Grigoropoulos et al., 2021) to conserve and not relay on this scares recourses reusing materials become central issue and because of the price of products to produce using recycling material reduced for many reasons, like the gathering cost of reusable material due to proximity to the society and reprocessing energy utilization, consumables relief.

Forti et al.(2020)& Thi et al.(2019) The amount of e-waste generated under each category shows at an increasing and decreasing rate compared to 2016 amount in referencing similar study. For instant, small IT and communication equipment category shows a 51.6% growths which is from

3.1 million tons in 2016 to 4.7 million tons in 2019. This tells us that attention has to be given to this category even it counts in fifth level out of the six categories in e-waste generation contribution.

2.3.3 Ways of E-waste Management

According to Li & Tee, (2012), managing e-waste has been taken place either formal and/or informal ways. Even industries in developed countries and the countries as well who are the major contributors to the global generation play major role to the informal way of managing their e-waste due to the imposing charges to be paid on their contribution to the generation due to extended producer responsibility strategy that the country implement. This has been done in the form of donation to the developing country that are in infant stage towards implementing reverse logistics for e-waste recovery late alone circular economy to make them free of responsibility throughout the products life cycle.

2.3.4 Reverse Logistics and Circular Economy in Industrial E-Waste Management

Circular economy as it is an industry system, with one of its most important tool reverse logistics especially in e-waste particularly in mobile phone return mostly found in the form of parts and component level gives a competitive power and opportunity due to their valuable material which are recoverable with in them.

By the help of the fundamental building blocks of circular economy that are, material and product design, new business model, global revers network and enabling condition for a company can in a better way transit so that competitive advantages in respect to financial, social and environmental be quire.

Reverse logistics in managing flow of returns in a lowest cost and dispose safely and circular economy in the ever circularity of materials gives ultimate advantage for a company and a country even the society through recapturing values from unused and discarded products.

Summary of literature survey

1. Articles based on their year of publication

Year of publication	Number of Articles
2021 - present	13
2016 - 2020	47
2010 - 2015	21
2004 - 2009	12

Table 2-1 Articles publication by their publication year

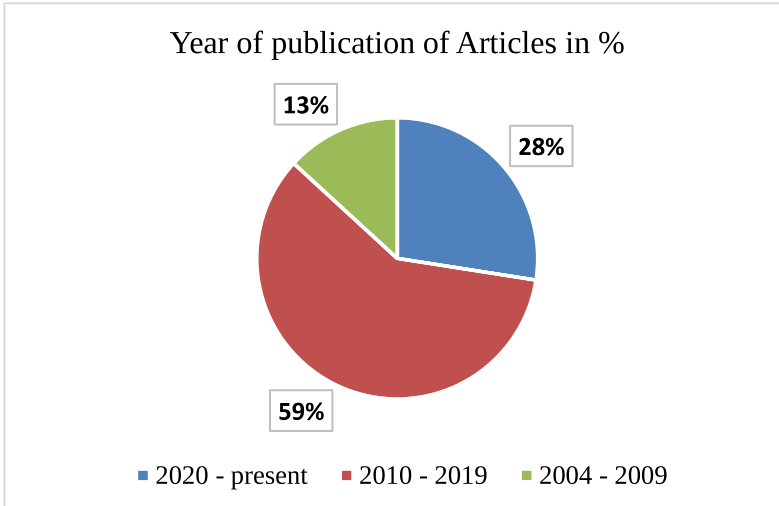


Figure 2-3: Graph of articles publication

As indicated above in the table and graph literatures written in near future are more assessed than conducted before long time and this indicates that the issues are still current critical one and the problem still need attention since not yet solved.

2. Data base Vs number of articles

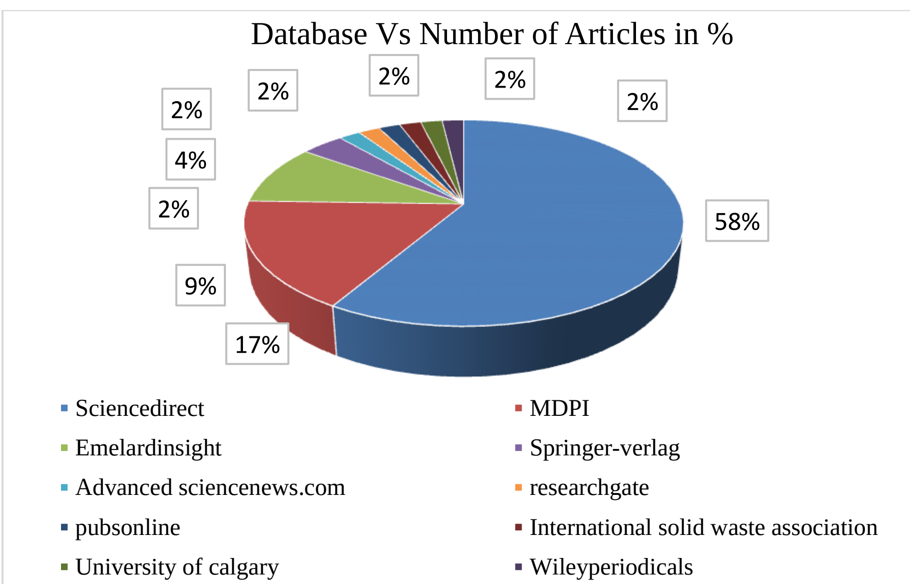


Figure 2-4: The data base vs. articles

The four top data bases that count more that 90% of the articles are sources of Science direct, MDPI, Emerald insight and springer with percentage of 58%, 17 %, 9% and 4% respectively. This shows that most of the studies related to the issue have been documented in these data base and can search for further work on them.

3. Publication VS number of articles

Publisher	**Number of Articles**
Elsevier	35
MDPI	12
Emerald	6
Tailor and Francis	5
Springer	4
Wiley	3
Research gate	3
Inder science enterprises ltd	2
Others with 1 articles	4

Table 2-2 Publishers and articles

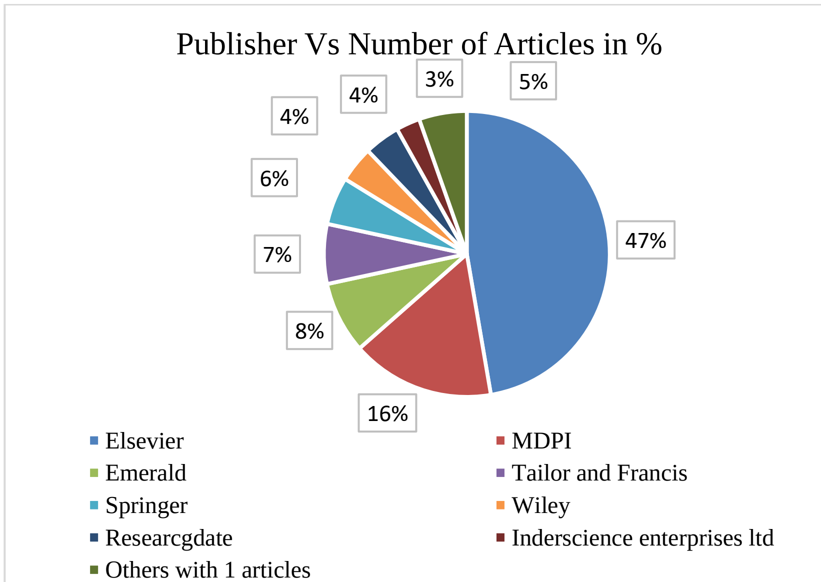


Figure 2-5: Publishers share versus the articles

The top three publishers Elsevier, MDPI and Emerald publish more than 50% of the total articles referred in this research. But explicitly Elsevier takes a share of 47%, MDPI 16% and Emerald 8% and the rest from 7 to 3% which gives a direction to any work related to this issue to search on them.

4. Areas of Focus

Focus Areas	**Number of Articles**
Reverse Logistics	36
E-waste	32
Circular Economy	18
WEEE	9
Supply Chain Management	6

Recycling	5
Remanufacturing	6
Business Models	3
Multi criteria decision making	3
Sustainability	6
reverse supply chain	5
optimization	3
Programming	5
Management	3

Table 2-3 Area of focus

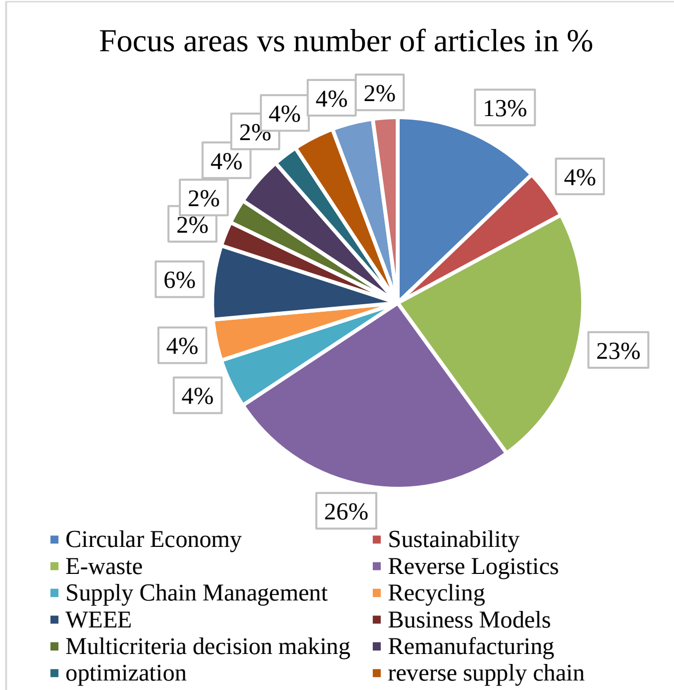


Figure 2-6: Focus area versus number of article

The top four focus area or most assessed articles which written on reverse logistics, e-waste, circular economy and waste electrical electronics equipment (WEEE) whereas three articles written on supply chain management, remanufacturing and sustainability in equal amount.

2.4 Literature Gap

1. There are many factors which affect implementation of reverse logistics for environment and economics sustainability. Off-course, these factors are either driver which motivates or forced to the implementation whereas the others are barriers which hinders from implementation of reverse logistics system and become obstacles from being effective. The level of specific barriers or drivers affect the system differs from industry to industry and from country to country based on specific country government regulations, economic and technological capability, people awareness and culture even. So with this respect, research on developed and some of developing country have been done but not yet conducted in Ethiopian case. Especially in least developed country like Ethiopia other un-identified factor may exist which will affect the system. The circular reverse logistics can support and prepare ahead the country from facing the upcoming issues due to highly increase on growth of e-waste.
2. The research conducted on e-waste management through implementation of effective reverse logistics and adopting circular economy focuses on consumer electronics only and hard to find research conducted both end-of-life and/or end-of-use products(consumer electronics) as well as industrial e-waste generated from production process(component and part level waste) especially a country on which only assembling industries are working. Because it is the manufacturer which are mobile assemblers who play a role in generation of these e-wastes and it is also their problem as well on disposing or managing these e-wastes as they are responsible in handling failure under warranty of their product.

CHAPTER THREE

3. RESEARCH DESIGN AND METHODOLOGY

The main aim of this research is to develop Ethiopian industrial e-waste management through the design of the reverse logistics network. It has been achieved by assessing the current practice of e-waste management and reverse logistics system, investigating the factors affecting the system and design optimum reverse logistics network model with the help of circular business model.

The data type used to conduct this research is both primary and secondary where:

Primary data has been collected from mobile assembling industries, government regulatory bodies (Ministry of innovation, Ethiopian Environmental Protection Authority, Addis Ababa Solid Waste Management), mobile phone refurbishing center and former MIDI using primary data source of observation, questioner and interview.

Secondary data from other stakeholders who have connection with the issue (Ethiopian Investment commission, Customs Commission, Ethio Telecom, Ethiopian Standard Institute), mobile phone refurbishing center and former MIDI including mobile phone assembling industries through secondary data source using questioner format.

Literatures; articles and journals, research papers and books written in general on reverse logistics designing and factors affecting its implementation, circular economy and circular business model and e-waste management are reviewed giving attention to be as much latest as possible using searching engines of Google Scholar mainly, data bases of Emerald insight, Science direct, MDPI, Springer, publication of Emerald, Elsevier, Tailor and Francis, MDPI, Springer and journal of cleaner production, sustainability, supply chain management, resources, conservation & recycling, waste management, environmental management, logistics and environmental science and pollution.

3.1 Research Design

The research is a descriptive type since it is assessing the practical problem of Ethiopian electrical and electronics industrial particularly mobile phone assembling e-waste management problem and identify factors more affecting reverse logistics.

The study has been focus on the assessment of existing Ethiopian e-waste management system in identifying factors affecting reverse logistics network and design the network which identify the location where the collection center is located in the aspect of collecting larger amount of end-of-life/use MP and selecting number of collecting centers, and disposing site be located which minimizes environmental pollution, cost of inventory and transportation for industries and facilitate easily accessible to the back ward supply of e-waste.

This has been achieved through survey analysis of mobile assembling industries found in Ethiopian about their e-waste generation and management and refurbishing centers on logistics, supply chain and reverse logistics by analyzing both qualitative and quantitative data.

3.2 Method of Data collection

Here data collection method has been a major concern on identifying appropriate data from appropriate source to come up with the solution for predefined problem.

3.2.1 Primary source of data collection

The qualitative data from the primary data source; Ethiopian MP assembling industries and the mobile refurbishing centers, the sector supporting institute (former MIDI), and the major stakeholders including regulatory bodies (Addis Ababa Waste Management Agency, FDRE Environmental Protection Authority and Ministry of Innovation used to assess the current e-waste management have collected through;

a) **Observation and visit:-** only on mobile assembling industries and the mobile refurbishment center production process, facilities for their e-waste accumulation and technologies they are using.

b) **Interview:-** from mobile assembling industries, mobile refurbishing center and leaders of FDRE Environmental Protection Authority, FDRE Ministry of Innovation to assess and understand the current practice of e-waste management.

c) **Questionnaire format:-** from mobile assembling industries, mobile refurbishing center and leaders of FDRE Environmental Protection Authority, FDRE Ministry of Innovation to assess and understand the current practice of e-waste management. In addition other input data from Ethio Telecom to collect mobile subscriber by location, Ethiopian Investment Commission to collect licensed investors in e-waste recycling and Ethiopian Custom Commission for import of mobile phones and components and mobile export and Ethiopian Standard Institute for standards adopted on e-waste management and disposal related issues.

Table 3-1: Summary of research methods and data types

S.No	Stakeholder for data collection	Data types	Collection method	Data source
1	Mobile assembling companies	Qualitative and Quantitative	Observation, interview, questionnaire format	Primary and secondary
2	Mobile refurbish center	Qualitative and Quantitative	Observation, interview, questionnaire format	Primary and secondary
3	Ethio Telecom	Quantitative	Questionnaire format	Secondary
4	EIC, ECC and ESI	Quantitative	Questionnaire format	Secondary
5	Computer refurbish center	Quantitative	Document review	Secondary
6	MOI, EPA, AASWM	Qualitative and Quantitative	Interview, questionnaire format and literature	Primary and secondary

The quantitative and qualitative data gather from:

1. Mobile assembling companies, their production and waste amount.
2. Ethiopian Customs Commission, the imported mobile phone from abroad.
3. Ethiopian Investment Commission, the profile of mobile phone assembling companies and e-waste recycling companies.
4. Ethiopian Standard Institute, the standards that are adopted as Ethiopian standard related to hazardous e-waste management and disposal.
5. Ethio Telecom, the number of mobile voice subscriber in Ethiopia.
6. Former MIDI, mobile phone assembling companies profile and performance report and related data.

3.2.2 Secondary sources of data collection

Different press releases related to recycling, population, mobile phone voice subscription and digitalization are assessed for additional reference. In addition, information from their data base of PM assembling industries and refurbish center has used.

Literature Survey

The other most valuable and supportive data sources were literature and the search approaches of literature survey have been done through electronic database.

Literatures; articles and journals, research papers and books written in general on reverse logistics designing and factors affecting its implementation, circular economy and circular business model and e-waste management are reviewed giving attention to be as much latest as possible using searching engines of Google Scholar mainly, data bases of Emerald insight, Science direct, MDPI, Springer, publication of Emerald, Elsevier, Tailor and Francis, MDPI, Springer and journal of cleaner production, sustainability, supply chain management, resources, conservation & recycling, waste management, operation management, science, environmental management, logistics and environmental science and pollution to make closer understanding on current researches.

3.3 Data Analysis

1. To analyze the current practice of e-waste management to be able to investigate factors affecting the e-waste management in existing reverse logistics practice analyzed with expert's to identify the critical factor.

2. Conceptualizing the barriers and drivers which affect the implementation of sustainable reveres logistics.

3. For effective implementation of RL of the mobile phone waste adoption of appropriate business model taken place using Circular Business Model Canvas type of CBM.

4. Microsoft Excel used for data filtering, organizing and other analysis purpose for quantitative data.

5. Using AnyLogistix for the collection center location and network optimizing the network using network and transportation optimization windows of the software. It is a design and optimization tool for both the network and transportation to find best collection center location at optimal transportation cost.

AnyLogistix (version 12.5.3) software combines powerful analytical optimization approaches with dynamic simulation technologies. This will empower the researcher a comprehensive set of tools for detailed network analytics. It can also represent any unique supply chain logic or behavior in a model, including the detailed processes taking place inside the four walls through integration with AnyLogistix simulation software. Since supply chain models are all about statistics and anyLogistix can calculate any required supply chain metric this will give also an opportunity to research to optimize the network taking different iteration flexibly.

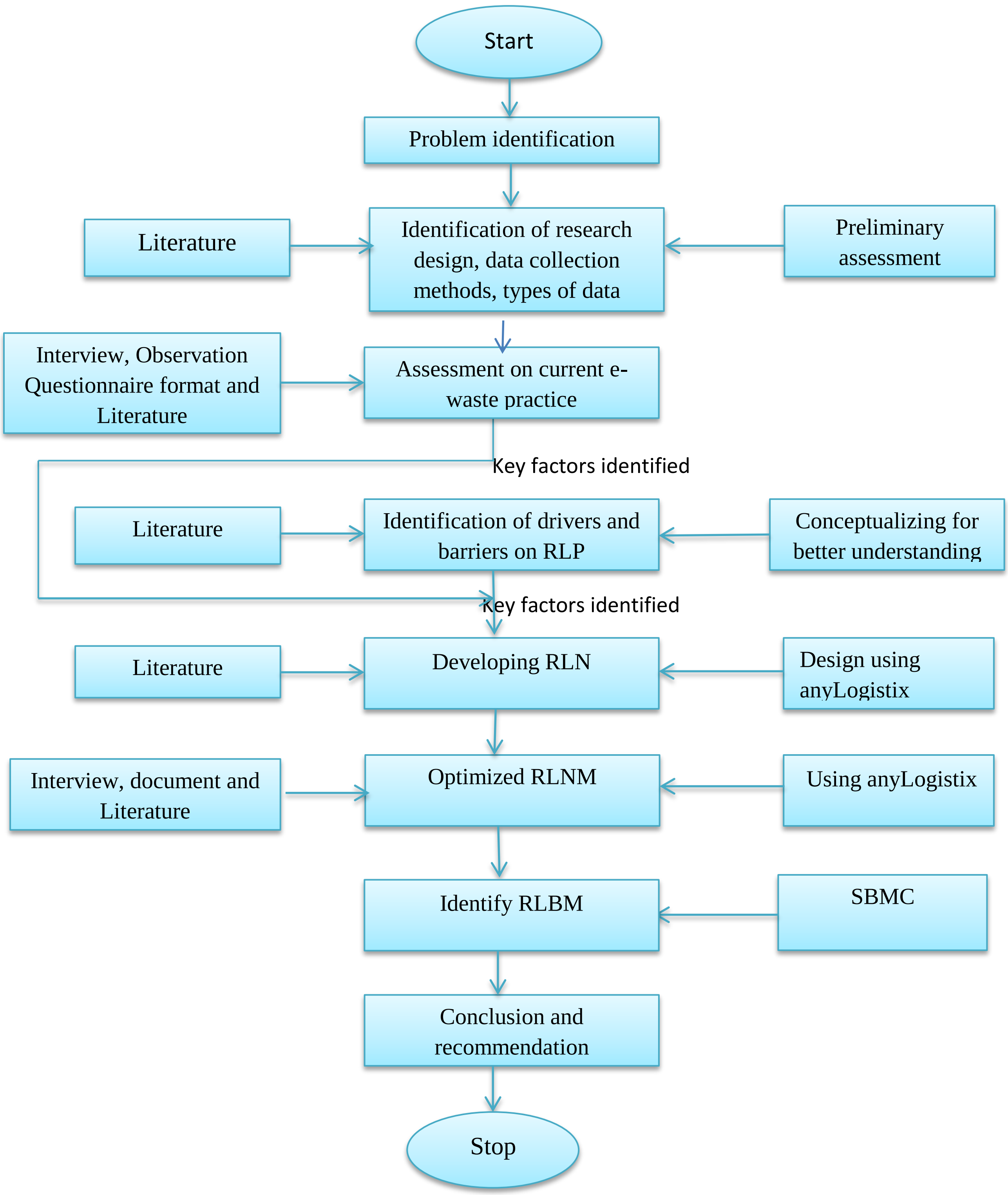


Figure 3-0-1 The research methodology flow diagram

CHAPTER FOUR

4. DISCUSION AND ANALYSIS ON REVERSE LOGISTICS NETWORK DEVELOPMENT AND OPTIMIZATION PERSPECTIVE

4.1 Assessment of E-waste Management Practice in Ethiopia

To assess e-waste management practice in Ethiopia first to identify the factors that affect the Akaki computer refurbish and training center from being effective and ends to close, two persons from major responsible organizations that have taken decisions to close the center MOI and EPA, and to assess the current practice of e-waste management particularly in mobile phone waste management concerned people are interviewed.

Table 4-1: people participated in the interview

Number of people interviewed	Organization	Responsibility
1	MOI	E-waste management directorate
1	EPA	Solid waste management compliance
4	From the 4 mobile assembling companies	GM, Plant Manager and Engineering Managers
3	Mobile phone refurbish center	GM, Operation Manager and CP Manager

Summering the assessment made with interview:-

The data collected through interview mainly on assessing the status of the government owned computer refurbish center and the current mobile phone refurbish center and e-waste management in general results to identify the factors mentioned below. These are:-

a) The center had no reverse logistics system as a strategic business plan to be effective in e-waste management particularly in computer refurbish so that there were problem of performing all RL activities required along the supply chain.

b) There had no collection centers with defined capacity and identified collection methods researched as well as centers for e-waste in particular.
c) Awareness creation for society hasn't been given.
d) There is no proper disposal system in electronic waste implemented.
e) Lack of incentive at policy level in e-waste particularly in mobile phone waste.
f) High transportation cost, unavailability of potential logistics provider in every corner of regional cities dedicated to e-waste transportation.

The results of secondary document reviewed are:-

a) Average capacity utilization of the mobile assembling company is 13.34% and average annual production 2.6million.
b) Average amount of component e-waste is 0.67% in number of the top 10 mobile components from the total produced.
c) There were more than 20 mobile assembling companies but currently this number drops to 6 with annual capacity of 20.3million.

4.1.1 General Over View of E-Waste Management Practice in Ethiopia

People live specially in urban part of Ethiopia prior to industries start producing EEE they are using them accessing from different source and were they finish their life time and or failed to give their intended purpose they were end up to be waste and disposed in any way be it in their surroundings, other municipal solid waste, in the form of sell with a least price to serve as a spare part for informal repair.

While industries start producing some of these EEE together with their tendency of using them particularly in this digitalization, huge number of these EEE are in use specially computers, mobile phones, televisions, ovens, washing machine, refrigerator and finally they also ends up as waste.

Due to affordability towards this equipment to satisfy the demand for instance computers for schools and medical centers for rural area reusing is the approach selected. To under gone this strategy, refurbishment one of the reverse logistics activity were selected and by collecting end-of-use and end-of-life computers from government organizations e-waste recycling center recapturing value through refurbishing then distribute to the required center.

As a first trial the first government owned e-waste recycling center were established by FDRE Ministry of Information Communication (former to reform) known as Ethiopian Computer Refurbishing and Training Center with over 54m birr capital around Akaki, under Akaki Kality Sub City in Addis Ababa, Capital city of Ethiopia with annual capacity of 100,000 computers to refurbish. The center were expected to refurbish end-of-use and end-of-life computer by collecting from government institution and importing abroad to provide for primary school and health institutions for the intention of multipurpose objective, for e-waste management to protect the environment and human, to satisfy the demand of computer for schools and medical centers and to capture values from end-of-use and end-of-life computers.

4.1.1.1 Major stages in product recovery processes in the computer refurbish center

1. **Acquisition**: the return product to be recovered was sourced by importing abroad and collecting from government office than collected in the refurbish center.
2. **Transportation and warehouse**: the mode of transportation used to transport these returns was either the refurbish center cargo truck or the disposer office transportation facilities.
3. **Inspection and disposition**: the collected end-of-use and end-of-life computer have gone disassembled, the component and parts have inspected then functional and nonfunctional components and parts have stored in their respected place. The functional parts then transferred to the refurbish process to produce new product from them. It is in this stage that the plastic or polymer and metal parts are sorted.
4. **Remanufacturing and refurbishing**: the functional parts and components selected and stored have gone through remanufacturing and new computer were produced. Ultimately these products were transferred in to marketing.
5. **Marketing**: the refurbished computers were supplied to schools and medical centers found in rural village and generate revenue. The center even export this refurbished computers and generate hard currency to the country.

4.1.1.2 Reverse Logistics Activities of the refurbish center

Regarding the reverse logistics activities performed in the center under the three product recovery management.

1. Direct reuse- if the return product which is end-of-use and end-of-life computer could give function it would directly be given to other parties like schools and medical center which are in need of computer but do not have it at all or in very large demand for use after giving a minor maintenance.
2. Product Recovery Management- (Repair, Refurbish, Remanufacturing, Cannibalization and Recycling).

   In the center, regarding these activities, repair and refurbish were the activities performed potentially and to some level remanufacturing. But not recycling. There were collecting them to disposal as they are not recycle them especially what are left from the above processes which are components or parts and other non-reusable parts like glass and plastic.
3. Waste Management- Incineration and Land filling

   This part of the reverse logistics activities was not implemented. All the left materials were collected in the centers.

4.1.1.3 Policy and Legal Framework towards E-Waste Related Environmental Issue

As a country, Ethiopia signed an international treaty concerned environment through e-waste management, disposal and cross boundary movement. These are;

The Bamako Convention on the Ban of the Import into Africa and the Control of Trans-boundary Movement and Management of Hazardous Wastes within Africa. January 30, 1991, The Basel Convention on the Control of Trans- boundary Movements of Hazardous Wastes and Their Disposal, designed to reduce the movements of hazardous waste between nations and specifically to prevent transfer of hazardous waste from developed to less developed countries. And also intended to minimize the rate and toxicity of wastes generated to ensure their environmentally sound management as closely as possible to the source of generation, and to assist less developed countries in environmentally sound management of the hazardous and other wastes they generate. In addition; there are proclamation No.1090/2018 "Hazardous Waste

Management and Disposal Control Proclamation" on how to transport hazardous waste, "Solid Waste Management" Proclamation No.513 /2007, "Environmental Impact Assessment" proclamation no. 299/2002, "Environmental pollution control" proclamation 300/2002, "Public health protection" proclamation and regulation No. 425/2018 "Electrical and Electronic Waste Management and Disposal", The Ethiopian Environmental Policy that was approved on April 2, 1997 also in place.

4.1.1.4 Standards Adopted and Customized

There are standards that Ethiopia has been adopted from ISO standards for the intention of managing e-waste in general, controlling the management and disposal of hazardous wastes specifically. There are two in number and both are compulsory standards. These are:

1. CES 326: 2022 Solid waste management – Requirements.
2. CES 327: 2022 Electrical and Electronics waste(E-waste) management and requirement.

4.1.2 Overview of the Mobile Phone Assembling Company in Ethiopia

Following the Ethiopian government plan known to be ambitious plan named Growth and Transformation Plan which had taken place in two phase of GTP I and GTP II five year strategic plan in each phase which were stayed from 2008 to 2012 and 2013 to 2017 focus given on transforming to industry lead economy overtaking the agricultural lead economy. Many foreign direct investments were flooded and out of the many, the mobile assembling industry investment were the one which starts assembling mobile phones in the country for the first time and reaches from non to more than 20 companies in number with capital of more than 200,000,000 birr.

As the whole component that is the input for producing mobile phone is sourced abroad and needs country hard currency, companies are challenging to get adequate supply of this hard currency to satisfy their input demand so as to utilize their capacity of assembling mobile phone. Due to this and other case many mobile phone assembling companies stop their production and quit their business totally so the number drops to 6 companies operating until this data is collected.

4.1.2.1 National Capacity on Mobile Assembling and Utilization

The national production capacity with the 20 mobile phone assembling companies at the end of II GTP were reached more than 25,000,000 pieces annually but as the report and assessment shows that the companies utilize not more than 25% of their capacity due to many reasons. In addition, a large number of mobile phones were also imported both legally passing regular customs clearance and illegal in contraband and even through visitors, business persons and abroad travelers of any other reason and sale in the country then people have been accessing from any of these sources and using them as well.

The 6 currently working companies have a capacity of more than 20,000,000 mobile phones and 5 of the factories are located in Addis Ababa and the rest is in Bahir Dar with market destination of all over the country. Regarding the investment type two of them are fully foreign owned, one is joint venture and the rest two of Local investor.

Table 4-2: Current operational mobile phone assembling company and their annual capacity

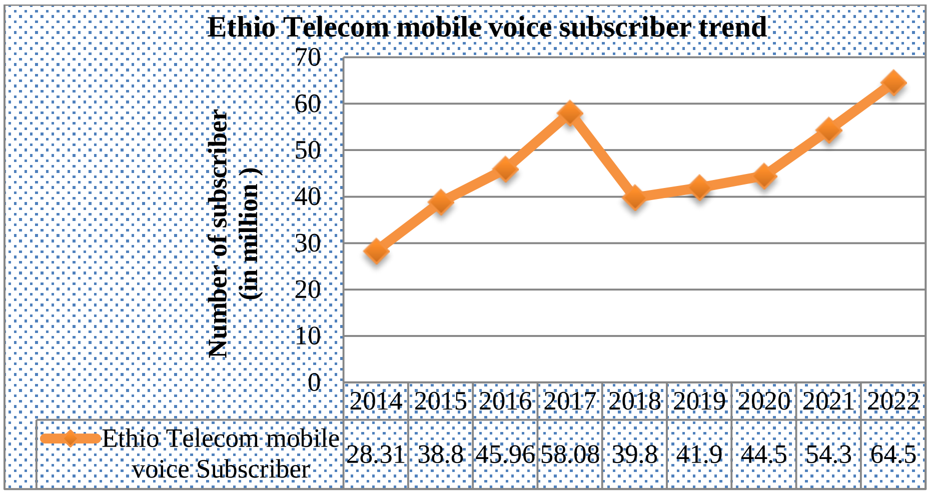
S. N	Number of mobile phone assembling company	Installed Annual production capacity	Location	Reverse logistics status	After sells service availability
1	6	21,500,000	80% Addis Ababa and 20% Bahir Dar	All didn't implement	80% have the facility but 20% not

Data source: interview made and MIDI report

Due to the effect of globalization and accessibility of the products in the market and maintenance service outlets found in the country and nearby cities of the customer, the tendency of using mobile phone becomes increased.

Now a day as a result of digitalization on financial services for instance; making payment, money transfer and air time purchasing makes people IT dependent. So demand and utilization of MP is increasing. Even people leaving in rural village and farmers begin to use mobile phone to exchange information about many issues like the price of their agricultural product and receive their many which plays a role in increasing number of mobile voice subscriber and ultimately MP users. This in general attracts mobile assembling companies' investment in the country.

The data from Ethio Telecom tells us that there are currently more than 64M voice subscribers in the country on July 7 2022. With the assumption that if every subscriber have been using a single mobile phone for a Telecom line, there are at most 64M mobile phone apparatus available in the country which will end up end-of-life when it reaches its life span or get damaged. The past ten years data on subscription indicates there is 15% rate of growth on average yearly.



Data source: Ethio Telecom

Figure 4-1: Mobile voice subscriber trend with Ethio Tele com

4.1.3 Mobile phone waste reverse logistics in Ethiopia

The mobile phone assembling companies found in Ethiopia they all are engaged in assembling. Due to the requirement, investment engaged in mobile phone assembling and sale their product in the country required having after sales service for under warranty products. Thus all of them have this center and handle their under warranty product failure. All the parts and components serve as an input for mobile phone production comes from abroad mainly from China. They are fully dependent on country hard currency, from the last four years on wards they are suffering on this hard currency for the fulfillment of their product input as there is no company who supplies their components and parts in Ethiopia. As a result they are using less than 15% of their capacity. But with four recent years more than 10million mobile phones are produced and marketed in the country apart from the imported one.

All these sold mobile phones either locally produced or imported when they get failed in giving function in relation to damage, service life or obsolescence the user may get revised, transferred to other user or kept them in-house.

Table 4-3 Production history of mobile phone in the country

	Production in pieces			
Number of assembling companies	2019	2020	2021	2022
6	3,259,588	2,036,292	2,097,144	2,678,457
Export share (%)	27.3	19.4	10.4	0.67

Source: Mobile assembling companies and former MIDI

E-waste generated from assembling process at the company and at their after sales service center is either disposed through sale to informal recycler or trader, municipal wastes or accumulate in their warehouse including mobile phone battery.

4.1.3.1 Maintainability and repair-ability of the return

The broken and damaged mobile phone gets maintained if the part and or parts cause failure is maintainable and the parts to be replaced the failed parts can be accessible. These parts could be new imported from abroad and local from used mobile phone.

The collected mobile phone parts for instance PCB, LCD, camera, mice, speaker, battery, which are failed totally during assembling process in the industries and from maintenance service provider centers know to be e-waste are disposed to either e-waste recyclers, to garbage with municipal wastes or export. But currently individuals most of them are informal recyclers collect these e-waste from different source with different method and recycle improper way, dispose to other recycler in the form of selling the material they are not interested in or unable to recycle or export to some extent. But the companies and the refurbish center are collecting them and store in their ware house or other place for future disposal in either of the forms. On the other hand, the individual mobile phone repair shops have been thrown these e-wastes to anywhere.

4.1.4 Current RL status of the mobile phone assembling companies towards their e-waste management

Despite of the informal recyclers, there are two centers doing activities related to e-waste management in the country in addition to the Akaki computer refurbish and training center which is not currently working. Both of them are independent entities that are third party recyclers which are not engaged in assembling mobile phones. One is in mobile phone refurbish and the other in e-waste recycling. There are;

1. The refurbishment center

The mobile phone refurbish center start operation before a year and has only below two years' experience with the aim of providing global maintenance service for both under and out of warranty a company and its family brand products. It is dedicated only on mobile phone, taking over the after sales service issue of the assembling company product which is under warranty as well as out of warranty the same brand product.

a) The reverse logistics system

The refurbish center established a total of 14 operation service centers (OSC), 78 collection centers and 3 stores all over the country which are dedicated in giving maintenance and repair service to the customer, collecting mobile phones from the customer for repair and for storage of collected mobile phones and parts respectively. One dedicated plan, they call it line 4 is performing all the activities to be performed in the center which especially couldn't be done at operation service center/branch.

Table 4-4: Operational service center and collection points as per the product distribution density

S.No	District	City	OSC	CC
1	Central Ethiopia (Addis Ababa)	AA1	1	5
		AA2	1	6
		AA3	1	5
2	Northern district	ND1	1	4
		ND2	1	7
		ND3	1	6
		ND4	1	6

		ND5	On progress	4
3	Southern district	SD1	1	4
		SD2	1	8
		SD3	1	5
		SD4	1	6
4	Eastern District	ED1	1	6
		ED2	1	6

Data source: Interview with OSC and CP managers as well as general manager of the refurbish center and their report.

Out of the 78 collection centers 16 of them are in central Ethiopia, Addis Ababa at different places with the assumption of denser population and repair shops location.

The method used to collect the return mobile phones is the point of purchase/collection at the retail outlet. The collected mobile phone on collection center are transported to the stores then to refurbishing plant with ordinary dry cargo trucks mostly using logistics service provider and pay for the service, otherwise air transport when there is a security issue in some case on the roads. They are, in addition, process the transportation by themselves when the collection point is located out of the logistics service provider coverage and found very close to the OSC.

In the refurbish center the plastic and metal parts generated from the mobile phone refurbishment process are collected to dispose in the form of sales for their respective recycler keeping the requirement of the recyclers. But here the metal parts found in the plastics part should be isolated with sorting and segregation.

b) Service Operation Procedures

When customers came to the branch seeking maintenance service to their mobile phone, product originality and warranty status checking are the first things they perform for pricing purpose then investigation of the failure type takes place to categorize based on their condition under the 3 categories. These are;

1. Whether the failures are maintainable or not, then repair but if the required parts to be replaced is not available in their hand process to import the parts from china then for new parts replacement takes place.

2. End- of-life

   Disassemble parts manually and select functional parts and store good material category then perform refurbishment so that the products will be given to the customer or serves as a replaceable for those who can't wait till their own mobile phone maintained.

   The bad materials know to be e-wastes identified and stored in bad material inventory have three options, exporting, locally disposing or further component disassembling.

3. Total damaged

   Here the phones are disassembled manually and identify parts if any which can be functional then follow similar procedure.

For battery case isolated package is using since it is exploitable and contain more hazardous substances which can cause series damage on environment and human health.

The center collecting an average of 8000 mobile phones monthly all over the country seeking for repair service and for the service given for under warranty is free of any charge for the customer but the company covers the charges whereas, in out of warranty case, service charges are expected to be covered by the costumers themselves.

c) Major services given in the mobile phone refurbishment center

Based on the level of failure or repair requirement there are three categories in the center staring from operating service center to refurbish center to go through appropriate processes.

Simple level

1. Software update with version problem.
2. Connection for simple connectivity problem/loose problem/
3. Minor repair and part replacement.

Medium level

1. Part replacement: from small to major part failure including board either main or sub boards of the PCB part failure replacing the entire board change.

High level

1. Screen failure: for broken glass, back light failure and touch pad issues can be maintained the latter service is given in the refurbishment plant, plant 4, whereas the failure under the first two categories which are under the minor service maintenance can be handled in braches level.

d) Cost consideration for service charge

The cost to the service they have given is calculated using CRM system considering cost of parts used for replacement, operating service charges and transportation cost including their margin.

Even if the mobile refurbishment center is the only a single brand oriented refurbish center and get guaranty on the originality of the parts to be replaced and the service they are offering customers are complaining on the price they request to the service. This is mainly, because of unclear calculation and generalization on the costing performed with the system.
Without taking in to consideration the transportation cost as per the distance traveled or cost incurred, either the customer themselves or the center collect the phones for repair and needs part to be replace the price of the parts are equal and higher to other repair centers. Due to this the center are losing considerable customers there by their incomes and ultimately their future customer to buy same brand.

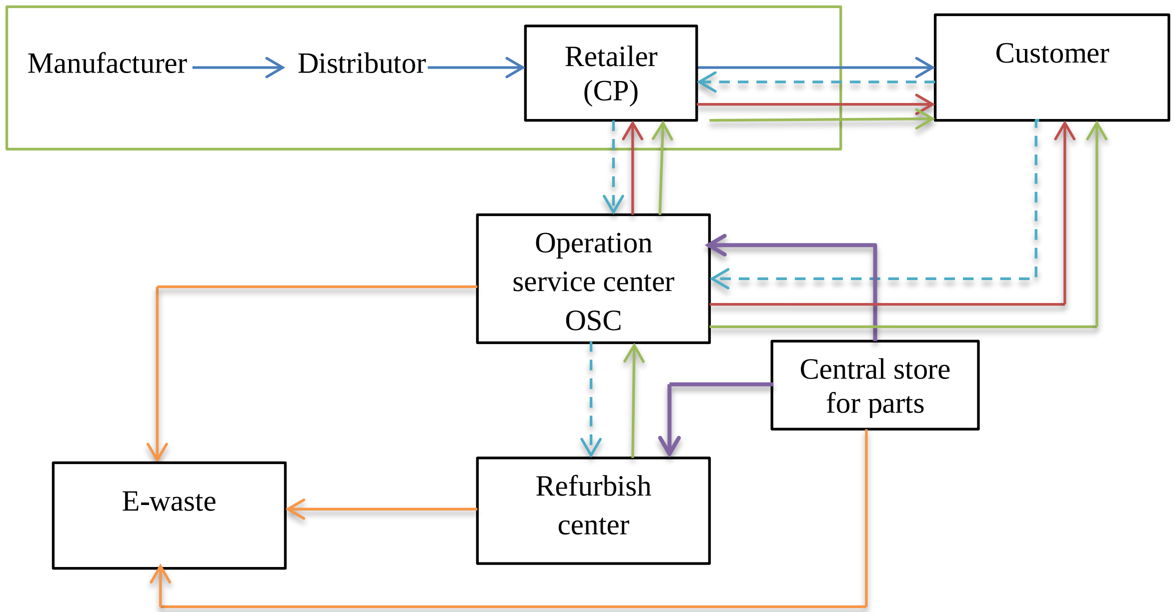


Figure 4-2 The business model of current maintenance based refurbish center

Source (KE, 2016) adopted and modified as per the center existing practice based on the interview made.

FWD → **PR** → **CF** → **RP** → **NRP** → **EW** →

e) Stages followed in product refurbish stages in the center

1. Acquisition

The initiator for the return mobile phones are customers where they bring their end-of-use mobile phone either directly to the operation service center and get repair when it is in the repairable condition, or through retail shops as some of them serve as a collection point for the center and transfer to operation service center for repair. All the return mobile phones are comes on the base of repair purpose from customers' initiative.

2. Transportation and warehouse

The collected mobile phones are transported to operation service center using different alternatives either by their own transportation, the collector themselves or local transportation service provider with any cargo tuck or air transport some time when there is inconvenient in the road or when out of the coverage of the service provider. The collected mobile phones are stored in three storage place/ warehouses, two of the stores are engaged in storing the collected mobile phone which is for repair waiting for repair at the operation service center but one is dedicated for storage of parts imported, return mobile phone waiting for refurbishing and refurbished products.

3. Inspection and disposition

At this stage, the collected return mobile phones get dismantled and tested then grouped as per their functionality status. Functional parts after selection grouped and stored under good inventory status the damaged parts which are not able to maintain stored in bad inventory and waiting for disposal.

4. Remanufacturing and refurbishing

The good parts selected and tested are go through refurbishment then nearly new mobile phones are produced and returned to the customer following the returned path.

f) The mobile refurbish center reverse logistics activities in material recovery perspective

1. Direct reuse- resale

Activities preformed in this level are when the coming mobile phones are in a very minor failure and returned to the customer with some correction, adjustment or refreshment without the need for any replacement in parts or components. The type of failure in this case is categorized in the simple level of the center grouping and handled in the entire operation service center.

2. Product Recovery Management

This stage of product recovery management covers repair, refurbish, remanufacturing, cannibalization and recycling. The refurbish center covers two of them, repair and refurbish. The return mobile phone at their product level need only some parte to be changed or replaced just restoring to the condition of working. In addition, from small to major part failure including board either main or sub boards of the PCB part failure and replaced the entire board change. And the return mobile phone at their module level replaced for upgrading its function through testing the critical modules to meet the required and specified quality level.

3. **Waste Management- Incineration and Land filling**

In this regard e-waste generated from replacement of the failed parts both in the repair and refurbish center are waiting for disposal in the form of sell for local recycler especially the metals and plastic parts and for export the e-waste mainly the boards.

4.1.5 Gaps on existing reverse logistics practice in mobile phone waste management

1. There is no mobile phone assembling companies in the country implement reverse logistics system as a strategic tool for their business sustainability.
2. There are no financial, environmental or social incentives applied to the consumer to promote for returning their end-of-life and end-of-use as well as obsolete mobile phones to the independent general e-waste recycling center.
3. The current mobile phone refurbish center target is maintenance based customer satisfaction through refurbishment.
4. National level or an independent recycler or mobile phone refurbishment is not available rather MP refurbishing center for only one brand and other many brands couldn't get this opportunity even.
5. There is no e-waste particularly end-of-life and end-of-use as well as obsolete mobile phones collection point or center which is convenient to collect them.
6. There is no proper disposal system implemented and concept of circularity so that value capturing through recovery of end-of life and end-of use mobile phones possible.
7. There is no data on amount of MP related waste generated from assembling and user.

4.2 Reverse Logistics Network Development

This section, as the research aims to solve the e-waste management problem particularly mobile phone waste management in Ethiopia holistically both for the industry and end users, deals with more about reverse logistics modeling and its one of enabling tool business model. E-waste either component or product level are not sufficiently managed in environmentally sound way yet. There are industries assembling mobile phone, repair shops of the assembling companies for their after sales service and individuals repair shops generate component level e-waste whereas end users sources of product level e-waste. To protect the environment and the society from exposing to these e-waste, as they contained hazardous material, and to gain economic benefit from recapturing the value of return products the proposed reverse logistics model referring the theoretical and practical has developed.

As mentioned in the earlier sections there are 6 mobile assembling companies producing mobile phones and sell to the local market except the one who export its product in African market. There are importers import finished mobile phones and sell in the local market as well, the country demand become the sum of the two sources just ignoring the illegal flow of mobiles to the market.

Based on the country legislation it is mandatory that an assembling company should its warranty in the country so that after sell service center has to be there and they are handling it even out of warranty too with customer payment. But since there are parts replaced the off function parts during repair, these parts are e-waste which are collected in their ware house but others are disposing them simply on the floor and to other wastes then collected as a municipal waste and cannot get properly managed as required to protect their harmfulness to the environment and human and lost their benefit from recapturing.

Customers after they replace their mobile phone due to end-of-use, end-of-life and/or obsolescent they simply kept with them.

Assembling companies to benefit from recycling their component level e-waste generated from assembling process and end-of life and end-of-use products from their customers collecting them through their retail shops, the country to gain economic benefit by recapturing the value and reenter in to the economy and to protect the environment and human from damage circularity driven reverse logistics model is proposed.

Component level e-wastes are generated both/either from manufacturer through mobile phone assembling process when the components and parts are completely failed and/or retail shop through parts replacement. Product level e-waste is end-of-life and end-of-use mobile phones from end users.

4.2.1 Assumptions for the model proposition

1. Mobile phone assembling companies and importers establish association and owned e-waste recycling centers which can serve as national mobile phone waste recycling center so that their as well as others component and product level mobile phone waste is recycled.
2. The Akaki Kality computer refurbish center is the mobile phone waste recycling center as well in addition to computer refurbishment to utilize the national facility/potential effectively.
3. The different materials which are produced from recycling mobile phone waste mainly component level waste are exported to the supplier/component manufacturers who supply mobile phone components and accessories for their input to assembling companies and to refurbish center.
4. The refurbished and repaired mobile phones are returned back to forward flow through secondary market. Since the end-of-use and end-of-life mobile phone which lost their value collected from customer gained value through repair are refurbish thus play a major roll on reducing utilization of resources by prolonging their life time.
5. Component suppliers also are product supplier of importers/whole sellers.
6. Customers are accessing mobile phone from both the secondary market and the ordinary new market.

To reduce, reuse and recycle in the perspective of circularity their by sustainability, the reverse logistics network model is proposed like the one shown below.

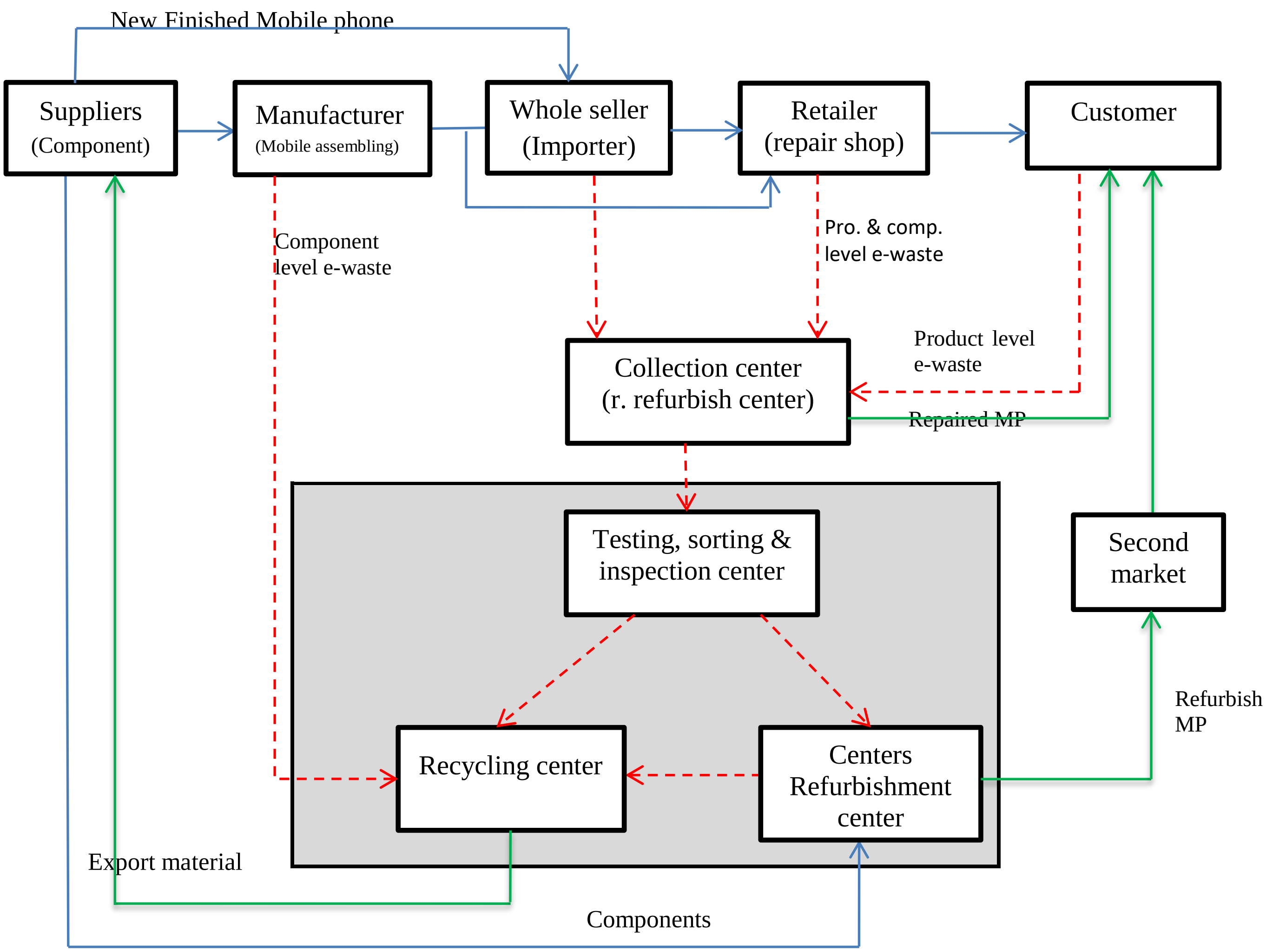


Figure 4-3: Proposed reverse logistics model in circular economy respective

Component and new MP forward flow

End-of-life MP and component waste reverse flow

Recovered (refurbish MP and recycled material flow

4.2.2 The 3Rs in the proposed model and their advantage towards sustainable RLS

Reduce

Regarding Circular economy, second market can play a major roll through reducing consumption of material in the form of raw material extraction to fulfill the demand for the manufacturing of new components simply by repairing the end-of-use mobile phone and make them functional so that it extends the life span of the product.

The product level collected mobile phone waste that is end-of-use mobile phone collected from customer when gets repair at the testing, sorting and regional refurbish center and return back to the market through secondary market to the customer, it could play a roll of reducing raw materials ultimately reduces generation of e-waste particularly mobile phone waste.

Reuse

Here also through repair with little adjustment and refreshment especially on the software and version update the end-of-use mobile phone can return to giving function though reuse. The repaired mobile can enter in to the system and customer can be able to buy and use them from buying new mobile and save their money to spend. Both strategies in the circular economy model can expand the life span of the end-of-use mobiles by re-entering to the system giving opportunity through repair and benefit customers to get functional mobiles with lesser price, especially to the low income group. Ultimately the country economy as the finished mobile and the component are imported abroad with large amount of hard currency.

Recycle

Recycling the mobile phone e-waste, the component and parts collected from assembling companies, repair shops at the retail out let, regional refurbish centers and central refurbish center/plant get recycled properly at environmental sound way, both valuable and hazardous materials can be managed and these material level products especially precious material for instance, gold and silver can export to supplier, who manufacture components to the assembling companies and products to the importer, and can serve as a source of hard currency to the country and the loop become closed and material could be circulate within the system.

Summary of the proposed model

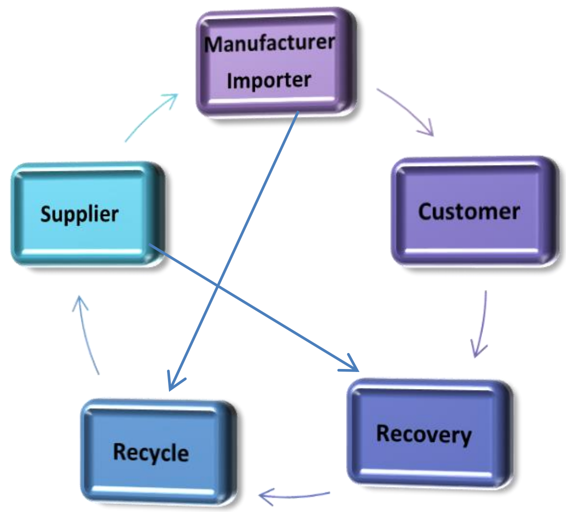


Figure 4-4: Summary on circularity in the focus of product forward flow and waste generation

4.2.3 The network description on the proposed model

The above RL model proposed to show the linkage of every center for the implementation of sustainable RLN in the perspective of circular economy through thinking about end-of use and/or end-of-life as well as component wastes of upstream holders are either collected, or dropped by the consumer, retailer, whole sellers and assembling companies at the collection centers which is near to them and recycle center respectively. The collection center assumes the sources for the supply of return products in the model to testing, sorting and regional refurbish centers.

The returned products in the testing, sorting and regional refurbish center are sorted as per their condition to make them ready for inspection before being sent either to central refurbish center or a recycle center. Inspection and sorting center is in the regional collection center then the inspected items can be sent to transfer to regional refurbish center for repair or be disassembled to identify the reusable parts and non-reusable parts.

The reusable parts can be sent to central refurbishing center and the non-reusable parts that cannot be reused can be sent to recycling centers. At the central refurbish center, the incoming parts from testing, sorting center can be reused again to create close to new products and then resold to a secondary market and the damaged parts can be sent to recycle center. Material level products from the recycling process can be exported to components supplier/manufacturer. The mobile assembling companies and central refurbish center purchase new components from component manufacturers/ suppliers to replace the damaged parts.

There is no transportation cost between suppliers/component manufacturing and central refurbish center because it can be covered by the supplier. So there will be no cost associated with this transportation. However, the transportation between collection centers and testing and sorting centers and between regional refurbish center and central refurbish center as well as recycle center be done either by outsourced trucks or in-house fleet and an associated cost will be incurred per kilogram of mobile phone waste per kilometer. Besides this, a fixed cost will also be applied for each unit of in-house transportation fleet to be purchased. Also there is no cost associated with transportation between testing and regional refurbish center because they are in similar place.

Additional consideration, the regional cities are taken on their population based on their percentage on the bases of the World Bank's Population data which is 120 million. 57 cities referring the customer are selected for the network design. Starting from 100km distance radius to consider closer to customer the collection sites to be 15 cites, for 200km 6 cities are resulted. Where as in the supply side, as more than 80% of the mobile assembling companies are found in Addis Ababa and it is the political, commercial and capital city of the country Ethiopia, the testing and sorting center and the central ware house is also selected to be in Addis Ababa. Since the already established e-waste refurbishing center is found in Addis Ababa and located in Akaki Kality, to minimize or avoid the new facility establishment cost and utilize the national resource the central refurbishing and recycling plant is taken to be in Addis Ababa too.

Table 4-5: Consumer side collection center/ DC for 100km distance

S.No	Collection/ distribution centers	Distance to site in km	Remark
1	Addis Ababa	100	To start with a more closer to the customer
2	Assosa		
3	Bahir Dar		
4	Chiro		
5	Dejen		
6	Dessie		
7	Dilla		
8	Gambella		
9	Gode		
10	Harer		
11	Jimma		
12	Mekelle		
13	Negele		
14	Nekemt		
15	Robe		
16	Ziway		

The result in the table shown above indicates that 5 of the DCs (Assosa, Chiro, Gode, Nekemt, and Negele) are at the location where the customer is located without any other network and the other two DCs (Gambella and Robe)are with only two customers which is 43.75% of the DCs are duplicate of the customer. Likewise with 200, 300, 400 and 500km are considered.

For instance, with 200km distance six collection center/DCs selected. These are:

Table 4-6 Consumer side collection center/ DC for 200km distance

S.No	Collection/ distribution centers	Distance to site in km
1	Addis Ababa	200
2	Dire Dawa	
3	Debre Tabor	
4	Hawassa	
5	Jimma	
6	Gode	

Mobile assembling companies are located currently in two distinct places, which are 80% of them are located in Addis Ababa different sub cities and taken as cluster for analysis purpose where as 20% located in Bahir Dar. Due to the concentration on the assembling company's location, denser population as result of urbanization seeking job opportunities, security and other criteria Addis Ababa could be the ideal large amount of mobile phone waste generation site. And large number of collection center could be assumed to have.

Table 4-7 Supplier side collection center

S.No	Collection centers	DC of fixed number case
1	Addis Ababa	2
2	Bahir Dar	

With this model the research major interest is collection of at most large amount of end-of-use and end-of-life mobile phone as well as components and parts generated through assembling process as a byproduct to safeguarding the environment from pollution and human from countless damage which have a direct relationship with it. The network would answer where and how many collection centers/DC to be established with the optimum amount of collection at each center. This have been done by identifying collection centers based on two determinant factors of the volume of return/end-of-use and end-of-life mobile phones as well as component level e-wastes and distance covered.

So, one of the two which is either the customer or suppliers side would be preferred by the analysis or mixed for better optimality.

4.2.4 Model Specifications

1. According to World Bank and United Nations Population Fund/UNFPA/ the population of Ethiopia in 2022 is 120million. About 39%, 57.5%, and 3.5% of them are found the age below 15, between 15 and 64 and above 64 years respectively. According to Ethiopian labor proclamation (FDRE, 1156/2019), 15 is the minimum age for work so, 15 and above to 64 is developmental force and most of them tends to live in urban city for job opportunity, education and/or trade and the like. So, from this 68.4 million can possibly use

mobile phone. With double SIM assumption that the organization allowed for a person, it implies 34.2 million mobile phones are available.

2. The data from Ethio Telecom, there are 66.8 million mobile voice subscribers end of 2022, and based on the organization regulation, a subscriber allowed having two SIMs. So, there is a minimum of 33.4 million subscribers. This is directly related with the number of mobile phones available in the country. Referring the same data for the last five years there are 26 20, 21, 22 and 27 million mobile phones users in 2017, 2018, 2019, 2020 and 2021 years respectively.
3. The 6 mobile phone assembling companies found in Ethiopia have a capacity 20.3 million annually and a total of about 13.2 million mobile phones are produced in five years from 2018 to 2022 with an average yearly production of 2.65 million at an average capacity utilization of 13.4%. From 2018 to 2020 there were 4 assembling companies with a capacity of 19.40 million but 2021 and 2022 with the current capacity of 20.3 million with 6 companies. Average 6 years capacity of 19.76 million.
4. The top ten component average total waste is 0.67. Mobile phone to be produced by the coming five years can be forecasted using average yearly production.

Table 4-8 Next five years local production forecast with the existing operational companies.

Year	Average Production rate (in %)	Production (in pcs)
2022	2.65	2,678,457.00
2023	2.65	2,749,436.11
2024	2.65	2,822,296.17
2025	2.65	2,897,087.02
2026	2.65	2,973,859.82
Total forecasted production by 2026		14,121,136.12

a) From the mobile assembling process e-waste generated at component and parts level are considered and the top ten components are PCBs, LCD/screen, camera and mic, vibrator, plastics and glass, speaker, LED, rare and front housing. Based on Singh et al., (2018) material characterization, average of feature and smart mobile phone weight is taken as 62.3gr. with the major components PCBs, LCD/screen, camera and mic, vibrator, plastics and glass, LED, rare and front housing, speaker and other are 13.56, 7.75, 1.21, 0.98, 25.62, 0.02, 13.0 and 0.17 grams respectively. Similarly data from assembling companies tells us that average weight of a mobile phone is 109gram. Battery which is one of mobile phone parts its average weight is 57.55 gram, the weight of the mobile phone mentioned above is out of this parts.

Based on the number of Ethio Telecom voice subscriber taking seven years trend which is from 2016 to 2022, there are 51.22, 39.8, 41.9, 44.5, 54.3, 64.5 and 66.8 million subscribers respectively. With similar assumption based on the organization regulation that is double line permission per head implies 25.66, 19.9, 20.95, 22.25, 27.15 32.25, and 33.4 million mobile phones were in use. Then based on the literature, life span of mobile phone in developing countries reach up to three years thus, the 25.66 million mobile phones that was in use at 2016 become waste at 2019, 19.9 million mobile phones that was in use at 2017 become waste at 2020 and 20.95 million mobile phones that was in use at 2018 become waste at 2021 and 22.25 mobile phones in use at 2019 become waste at 2022. So, the expected amount of mobile phone waste is 88.76 million end-of-life mobile phones present in the country within four years period referencing only mobile phone in use since 2016 that is at the end of 2022 or beginning of 2023. Likewise the 27.15, 32.25 and 33.4 million mobile phones that were in use at 2020, 2021 and 2022 respectively become waste at the end of 2023, 2024 and 2025. After two years the number of end-of-life mobile phones expected to reach more than 92 million.

Therefore:
Average weight of one mobile phone is 109gram (data from mobile assembling companies).

At the end of 2022 or beginning of 2023 amount of waste expected to be available is the sum of end-of- life/use mobile phone which is product level waste generated by users and component level waste generated from assembling process.

Average top ten component weight per component is 15.68gram (raw data from mobile assembling companies). Taking the waste generated from production of mobile phones from 2019 to 2022, average number of component waste percentage in top ten components is 0.67%. For data consistence on estimating the component waste generated from the total production, taking average annual production of 2.65 million for the years 2016 to 2018, additional 76,823 pieces of component waste have generated.

Total MP related waste = product level waste + component level waste

= 88.78M*0.109kg/piece + (76,823+102431)*0.015kg/component

= 9677.02ton+2.69ton

= 9679.71ton

So, on average more than 2400ton mobile phone related e-waste has been generated for the last four consecutive years. This amount become increasing in the coming three years.

92M*0.109g+1*3

10,031ton

This means, the end 2025 from the current available mobile phones in use from 2020 to 2023 years expected to reach 10,028ton.

Similarly, at the end of 2025 or beginning of 2026 expected end-of-life/use of mobile phones generated by users and the component e-waste generated from assembling mobile phone process become 10,031ton.

So, average of 3343tons annually or at an average of 31million mobile phones and more than 1ton of component level waste in each year ends up waste.

In this research the objective here is to design the reverse logistics network which can be able to collect at least 40% of end-of-life/use mobile phone as possible with selecting the optimum number of collection center at optimum location for optimum transportation cost attainment.

4.2.5 Network design for the selection of facility location using anyLogistix

The collection facility for end-of-life/use mobile phone is critical to identify the capacity that how much to be collected, where should they are to be located and also their number with optimim flow cost estimation. To design the network using anyLogistix, 57 customers at cities level in the country with a poputation of more than 61,000 in a city is taken and their locations from GIS map of the anyLogistix. Since there is no past experience and it is new study on the country, customer demand are assumption. The end-of-life/use mobile phone is product to be collected from customers through the distribution centers, the customer demand is the end-of-life/use mobile phones.

Procedure for GFA experment to design the network for identfying the optimum distribution center location/collection center in this specific study case.

Input data for the experment are;

- Creating customer and customer location
- Product to be colected
- Demand for every customer for the product

Case 1. The network design with a single distribution/collection center location considering the a city with very much denser in population, information technology and commercial, educational and political hub and also manufacturing.

a) Product flows table

Table 4-9 Product flow in one DC case

Product Flows

Period

	From	To	Product	Period	Flow, pcs	Distance, km	Flow Cost Estimation, pcs * km
1	◢ GFA DC	...(57)	End-of-life/use ...	Time period: 202...	Sum: 8,721,500	Sum: 15,950.79	Sum: 1,766,636,095.463
2	GFA DC	Mekelle Custo...	End-of-life/use...	Time period: 2...	259,000	505.101	130,821,170.487
3	GFA DC	Jimma Customer	End-of-life/use...	Time period: 2...	185,000	263.36	48,721,584.387
4	GFA DC	Axum Customer	End-of-life/use...	Time period: 2...	55,000	566.972	31,183,441.667
5	GFA DC	Dilla Customer	End-of-life/use...	Time period: 2...	170,200	295.346	50,267,901.531
6	GFA DC	Kombolcha Cu...	End-of-life/use...	Time period: 2...	162,800	253.59	41,284,521.917
7	GFA DC	Irgalem Custo...	End-of-life/use...	Time period: 2...	77,700	255.868	19,880,960.38
8	GFA DC	Gode Customer	End-of-life/use...	Time period: 2...	39,900	626.613	25,001,862.981
9	GFA DC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

In only 1 DC case under the above mensioned consideration, the product flow indicates that the amount of end-of-life/use mobile phone transported or collected are 8,721,500 pieces and the distance in km column tells us that the total distance covered by a given vehicle which is 15,950.97km to collecte the indicated amount to the required distribution center.

b) The demand coverage and the level of coverage in percentage table

Table 4-10 Total demand covered by distance in one DC case

Total Demand Coverage by Distance

	Distance to Site, km	Demand, %	Demand, pcs
1	0	20.983	1,830,000
2	100	32.166	2,805,400
3	200	47.315	4,126,600
4	300	72.631	6,334,500
5	400	86.255	7,522,700
6	500	93.89	8,188,600
7	600	99.543	8,681,600
8	700	100	8,721,500

The tabel shows that the distance coverage to satisfy the each level of demand; for instance to satisfy the 100 % of the demand, the maximum distance covered to the site is 700km radius this is in 1 distribution/collection center senario. With 99.54 level satisfaction can be achived bycollecting 8,681,600 pecies at a total diatance of 600km. radius.

c) Network designed with 1DC using anyLogistix GIS map

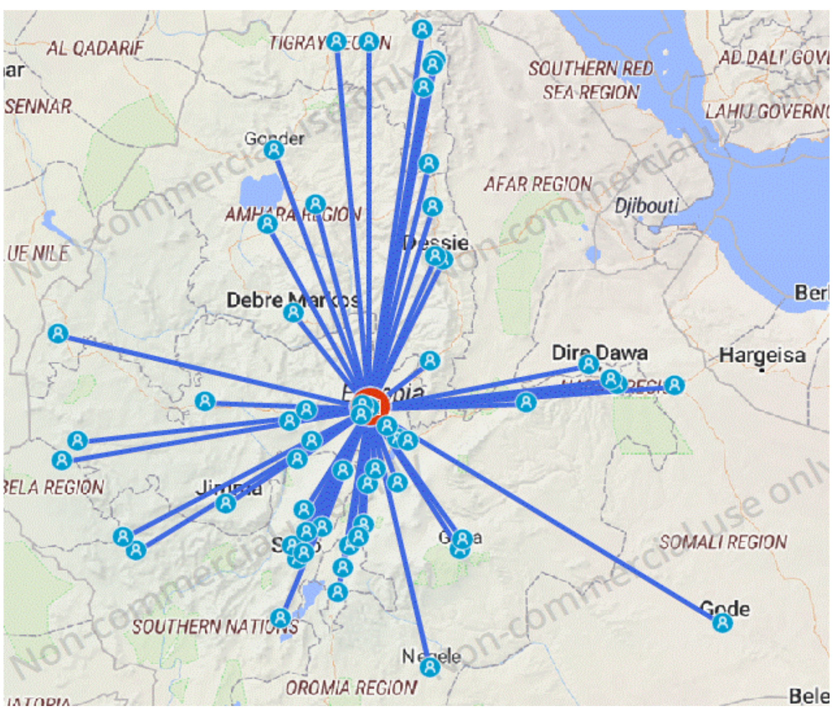


Figure 4-5: The network with 1 DC case using anyLogistix GIS map

Customers from every city send to collect their end-of-life/use mobile phones and component level wastes to the only one distribution center found in Addis Ababa.

Case 2. The network design on the supply side which is the distribution centers location is at the mobile phone assembling company, as they found only in two cities of the country.

a) Product flows table

Table 4-11: Product flow in two DC case

Product Flows

Period

	From	To	Product	Period	Flow, pcs	Distance, km	Flow Cost Estimation, p...
1	...(57)	...(57)	End-of-life/use MP	Time period: 2023-0...	Sum: 8,721,500	Sum: 12,115.311	Sum: 1,332,270,115.311
2	GFA DC	Butajira Custo...	End-of-life/use MP	Time period: 2023-...	131,400	75.312	9,896,024.315
3	GFA DC	Harar Customer	End-of-life/use MP	Time period: 2023-...	118,400	377.309	44,673,410.397
4	GFA DC	Irgalem Custo...	End-of-life/use MP	Time period: 2023-...	77,700	219.097	17,023,871.391
5	GFA DC	Adama Custo...	End-of-life/use MP	Time period: 2023-...	328,500	61.163	20,091,988.619
6	GFA DC	Jimma Customer	End-of-life/use MP	Time period: 2023-...	185,000	242.388	44,841,847.078
7	GFA DC	Arsi Negelle C...	End-of-life/use MP	Time period: 2023-...	87,600	148.316	12,992,493.863
8	GFA DC	Welkite Custo...	End-of-life/use MP	Time period: 2023-...	109,500	114.104	12,494,380.508
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Product flow indicates that the number or amount of end-of-life/use mobile phone transported to be collected which is 8,721,500 pieces and the distance in km column tells us that the total distance covered by a given vehicle which is 12,115.31km to collecte the indicated amount to the required distribution center.

b) The demand coverage and the level of coverage in percentage table

Table 4-12: Total demand covered by distance in two DC case

Total Demand Coverage by Distance

	Distance to Sit...	Demand, %	Demand, pcs
1	0	0	0
2	100	43.282	3,774,800
3	200	68.849	6,004,700
4	300	88.468	7,715,700
5	400	96.173	8,387,700
6	500	99.543	8,681,600
7	600	99.543	8,681,600
8	700	100	8,721,500

This tabel shows that the distance coverage to satisfy the indicated level of demand; for instance to satisfy the 100 % of the demand, the distance covered between customer to distribution center is 700km. this is in 2 distribution center senario.

c) **Network designed with 2 DC using anyLogistix GIS map**

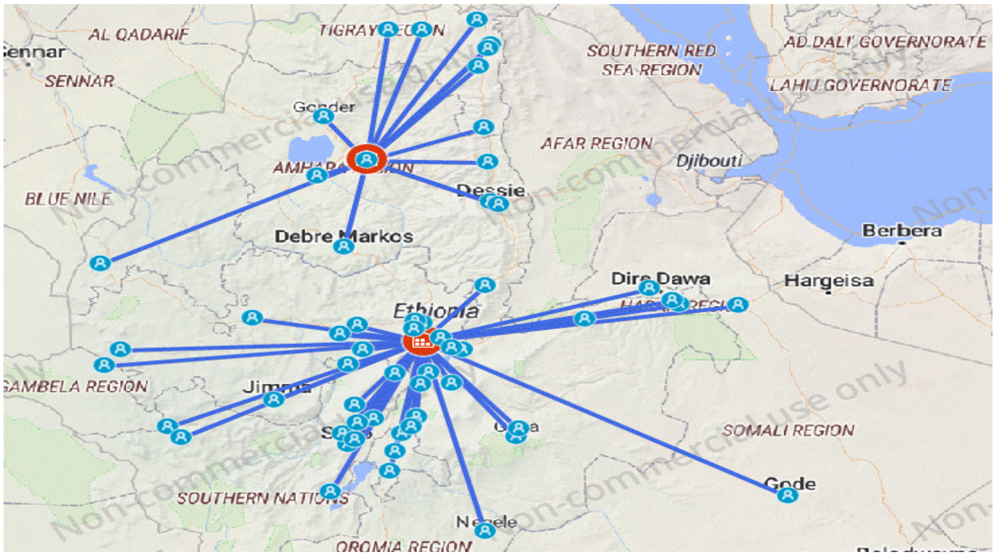


Figure 4-6: The network with 2 DC in the supplier side case using anyLogistix GIS map

The network designed above using anyLogistix shows that with 2 DC case, the DC are located in AA with 42 customer network and Debre Tabor 15 customers network where anyLogistix grouped as per their distance to attain optimal flow cost estimation.

Case 2. The network design on the customer side where 200km with fixed distance between customers and distribution centers unlike that of the above.

a) Product flow table with 200km distance senario

Table 4-13: Product flow in the fixed distance of 200km case

Product Flows

Period

	From	To	Product	Period	Flow, pcs	Distance, km	Flow Cost Estimation, p...
1	...(57)	...(57)	End-of-life/use MP	Time period: 2023-0...	Sum: 8,721,500	Sum: 6,183.991	Sum: 749,010,452.468
2	GFA DC	Jimma Customer	End-of-life/use MP	Time period: 2023-...	185,000	169.801	31,413,137.673
3	GFA DC	Mizan Teferi C...	End-of-life/use MP	Time period: 2023-...	30,400	178.024	5,411,933.41
4	GFA DC	Asosa Customer	End-of-life/use MP	Time period: 2023-...	45,600	199.962	9,118,272.962
5	GFA DC	Tepi Customer	End-of-life/use MP	Time period: 2023-...	41,800	157.01	6,563,002.071
6	GFA DC	Gambela Custo...	End-of-life/use MP	Time period: 2023-...	67,500	117.769	7,949,413.688
7	GFA DC	Dambidolo Cu...	End-of-life/use MP	Time period: 2023-...	19,000	88.235	1,676,471.207
8	GFA DC	Neqamte Cust...	End-of-life/use MP	Time period: 2023-...	170,200	116.351	19,803,012.539
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

From the product flow table above, it is possible to see equal amount of flow which is 8,721,500 end-oflife/use with lesser total distance of 6,183.39km which is by 48.69% lower than thhe total distance coverd in a single DC case and flow cost estimation 749,010,452.46

b) The demand coverage and the satisfying level

Table 4-14: Demand covered by distance in 200km distance to site case

Total Demand Coverage by Distance

	Distance to Sit...	Demand, %	Demand, pcs
1	0	20.983	1,830,000
2	100	53.774	4,689,900
3	200	100	8,721,500

This shows that, the 53.77% demand can be covered with 100km radius but the 100% demand covered at a distance of 200km radius. 0 distances mean the DC located at the location the customer found. Since AA DC is located at AA customer location the distance covered is 0.

c) The network of 200km radius distance to site using anyLogistix GIS map

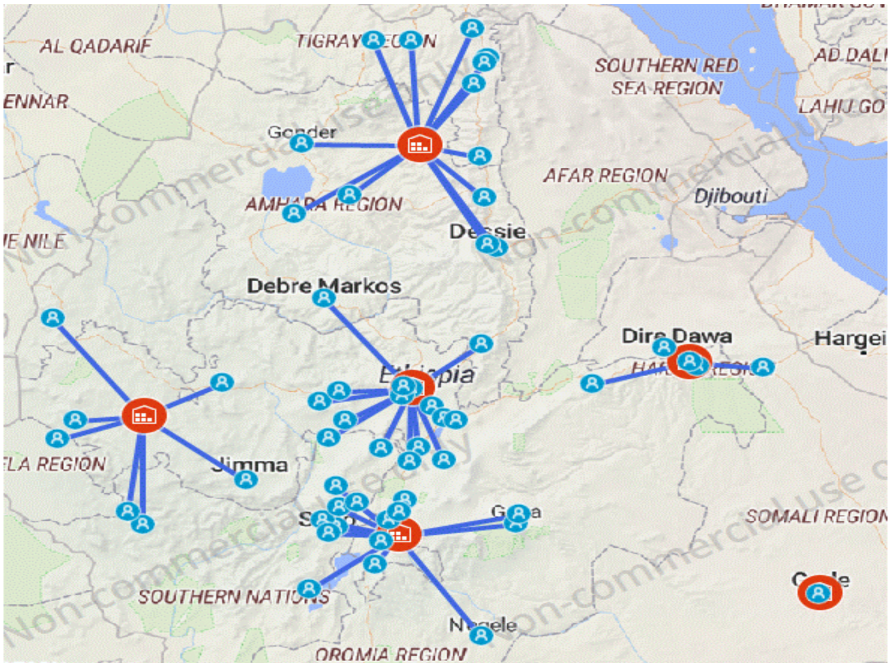


Figure 4-7: Network of 200km radius distance to site using anyLogistix GIS map

Designing the network with fixed distance 200km scenario, the number of DC the above network tells us is 6DC located in Hawassa, AA, Debre Tabor, Jimma, Gode and Dire Dawa with number of customer group of 15,16,13,7,1 and 5 respectively.

Case 3. The network design with 6 DC locations which contain the supply side and customer with indicated estimated transportation cost and distance covered.

a) Product flow with 6 DC

Table 4-15: Product flow with 6 DC

Product Flows

Period

	From	To	Product	Period	Flow, pcs	Distance, km	Flow Cost Estimation, p...
1	...(57)	...(57)	End-of-life/use MP	Time period: 2023-0...	Sum: 8,721,500	Sum: 6,471.367	Sum: 702,785,142.253
2	GFA DC	Gimbi Customer	End-of-life/use MP	Time period: 2023-...	32,300	121.194	3,914,574.37
3	GFA DC	Bishoftu Custo...	End-of-life/use MP	Time period: 2023-...	182,500	39.506	7,209,824.133
4	GFA DC	Mojo Customer	End-of-life/use MP	Time period: 2023-...	37,000	64.135	2,373,009.163
5	GFA DC	Addis Ababa C...	End-of-life/use MP	Time period: 2023-...	1,830,000	0	0
6	GFA DC	Sebeta Custom...	End-of-life/use MP	Time period: 2023-...	146,400	18.441	2,699,802.663
7	GFA DC	Butajira Custo...	End-of-life/use MP	Time period: 2023-...	131,400	109.182	14,346,563.071
8	GFA DC	Debre Birhan C...	End-of-life/use MP	Time period: 2023-...	204,400	116.147	23,740,502.927

The table above shows that, equal amount of flow of 8,721,500 with total distance of 6,471.36km and flow cost estimation of 702,785,142.25.

In fixed distance scenario of 200km, the number of DC to cover the demand by 100% is 6 which is the same in fixed number of 6DC scenario but the total distance covered in previous case lesser by 4.45% but flow cost estimation higher by 6.58%. This is because the optimum point towards minimizing the total distance coverage but in fixed distance scenario optimum point towards minimizing the number of DC.

b) The network with 6 DC using anyLogistix GIS map

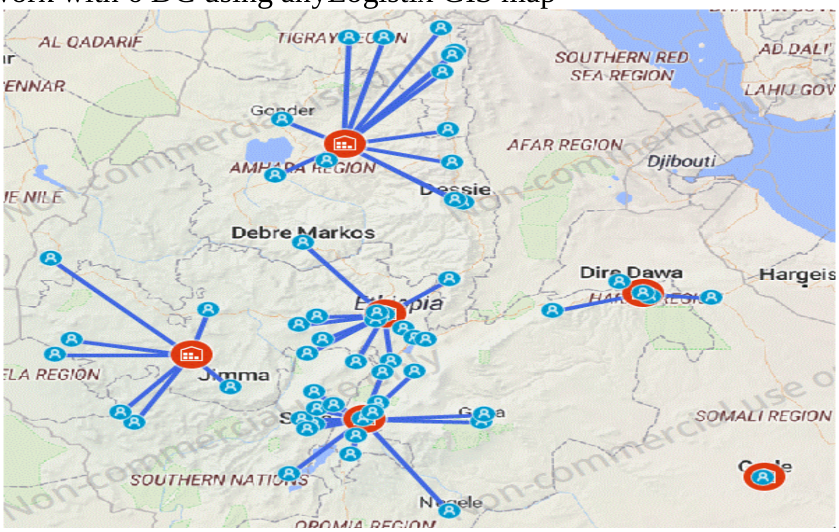


Figure 4-8: The network with 6 DC using anyLogistix GIS map

The designing network with fixed number of DC scenario shown above tells us that AA DC with 14 customers, Hawassa, Dire Dawa, Debre Tabor, Jimma and Gode with number of customer of 17, 5, 13, 7 and 1 respectively. The different is on AA and Hawassa DC with 2 customers as per their distance.

From these, it is possible to select the number and location of distribution center facility with minimum flow cost estimation computed using anyLogistix.

The same amount of flow to be collected which is 8,721,500 end-of-life/use mobile phones with different flow cost estimation, that is; summarized in the table below.

Table 4-16: Summary of the GFA experiment result for network design

S.N	Cases	DC(in number)	Amount collected	Distance covered	Flow cost estimation in million (pcs*km)
1	One distribution center	1	8,721,500	15,950.75	1,766.636
2	Supply focused facility location with fixed DC	2	8,721,500	12,157.69	1,332.270
3	Fixed number of DC	3	8,721,500	9,912.54	973.784
4	Fixed number of DC	4	8,721,500	8,721.5	805.669
5	Fixed number of DC	5	8,721,500	6,883.69	719.376
6	Fixed number of DC	6	8,721,500	6,471,37	702.785
7	Fixed number of DC	7	8,721,500	6,045.12	677.85
8	Fixed number of DC	8	8,721,500	5,182.88	569.07
9	Fixed number of DC	9	8,721,500	4,675.29	527.54
10	Fixed number of DC	10	8,721,500	4,505.48	517.16
11	Fixed distance of 100km	16	8,721,500	2,892.24	403.510
12	Fixed distance of 200km	6	8,721,500	6,183,991	749.010
13	Fixed distance of 300km	4	8,721,500	10,811.05	1,582.51
14	Fixed distance of 400km	3	8,721,500	11,520.80	1,483.73
15	Fixed distance of 500km	2	8,721,500	13,498.8	1,606.54

The network with fixed 10 DC case with GFA experiment in anyLogistx output as the table above shows the minimum flow cost estimation to collect similar amount of end-of-life mobile phone which is 8,721,500, but it does not mean it is optimal because as the number of DC increase or as the distance from site minimized the flow cost estimation definitely will decrease. So, optimal point should be selected with optimal total distance coverage.

The preferred network is network of mixed DC case, which contains the supply and the customer/demand which is optimal with minimum flow cost estimation for collecting optimum amount of end-of-life/use mobile phones.

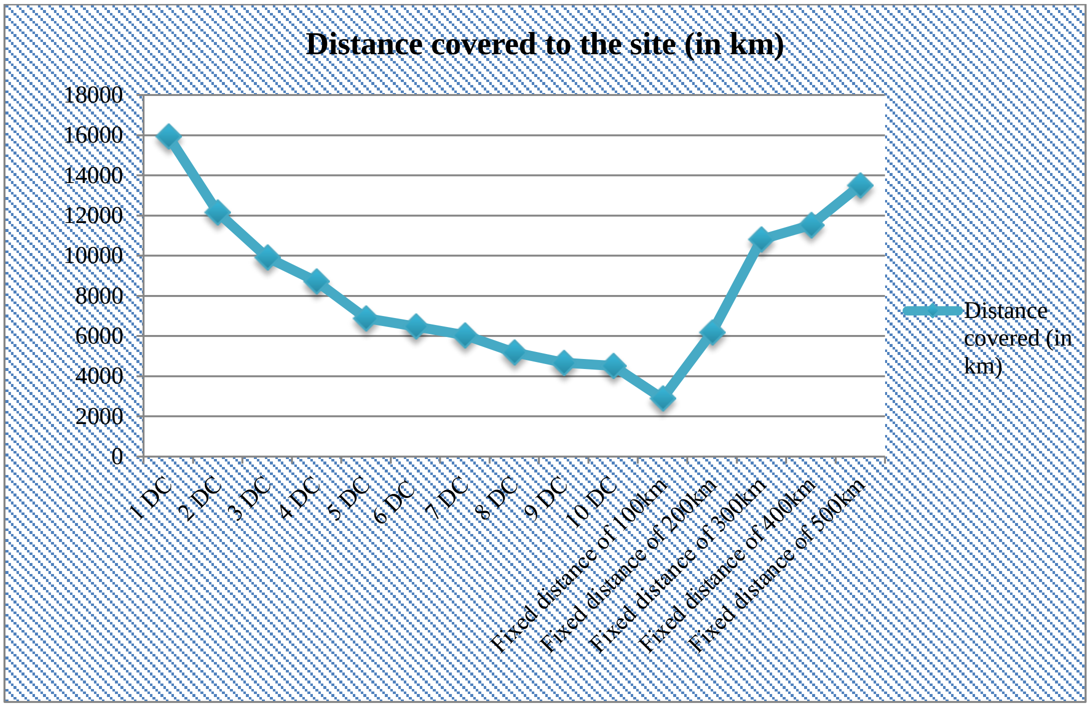


Figure 4-9: Distance covered to the site

When only one DC is taken, the total distance covered to collect the customer demand by 100% is near to 16,000.00 km, but as the number of DCs increase the total distance become lower and lower reaches about 4,505.48km with 10 DC. Similarly in case of setting fixed distance, starting from 100km, the number of DC where GFA experiment optimizes is by 16DC and the total distance coved become 2,892.24km but as the distance between site increases the number of DC decreased whereas the distance coved increase. At a fixed distance case of 500km, the number of DC dropped to 2 but the distance rise to 13,498.8km. So, here also optimum point should be identified.

As the number of fixed DC case increase, the distance coved decreased much but it does not mean better because, ultimately the collected end-of-life mobile phone has to be transported to the recycling center located in Addis Ababa and as DC facility required facility expense either in rental form or through investment, it led the reverse logistics system face higher investment with large fixed cost. So number of DC has to be limited and be optimum.

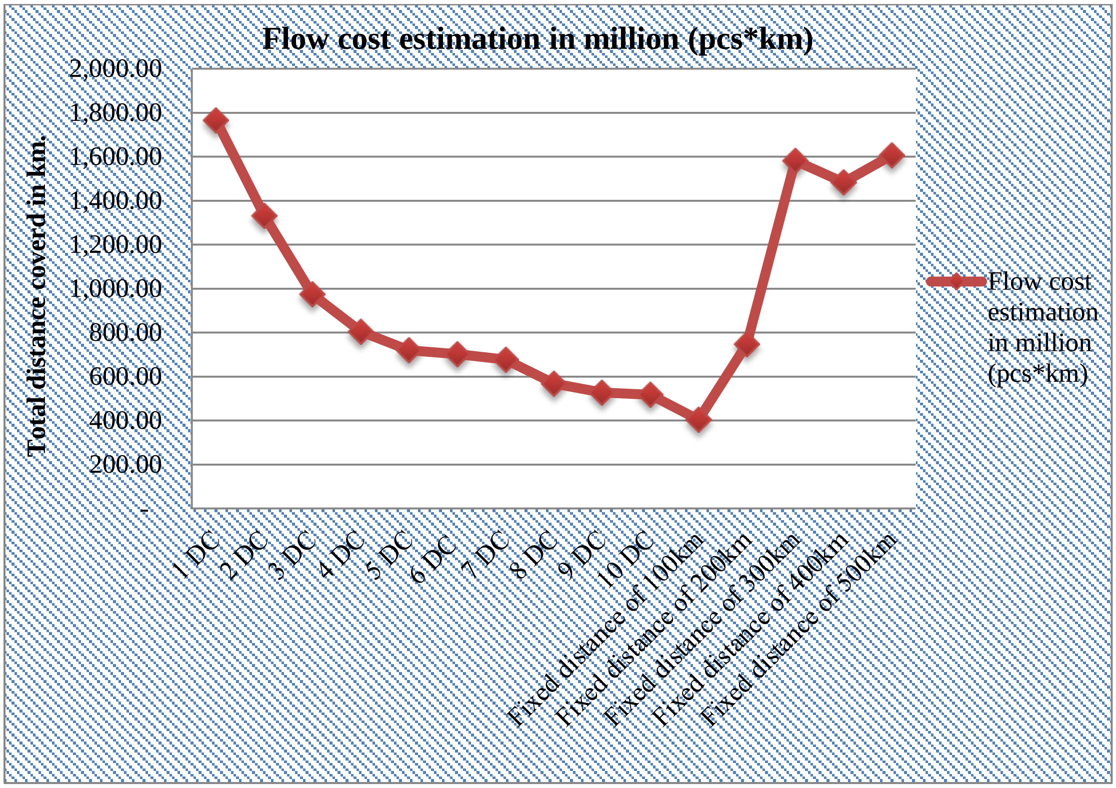


Figure 4-10: Flow cost estimation in a given fixed number of DC and distance in km.

Flow cost estimation is computed by GFA experiment with amount of flow in pieces and distance covered to collect, increasing distance has a direct impact on increasing the flow cost estimation and also it has direct implication on increasing in transportation cost.

So, as the graph above shows that as the distance dropped down the flow cost estimation also dropped and vice versa.

To select the best optimum number of DC and optimum flow cost estimation with its corresponding distance covered to collect the whole;

As the recycling center is located in Addis Ababa and all the collected end-of-life/use mobile phones has to be transported to the recycling center, average distance between Addis Ababa and the top ten populated cities are considered because they are more influential due to large population and urbanization. So that better dependency in IT which implies in larger utilization of mobile phones and ultimately generation significant amount of end-of life/use mobile phone.

Table 4-17: Top ten populated cities in Ethiopia and their distance from Capital AA

S.No	City as per their population	Population	Distance between AA and the City(in km)
1	Gonder	466,000	720
2	Mekelle	457,900	769
3	Adama	456,900	80
4	Hawassa	422,200	275
5	Bahir Dar	350,000	551
6	Dire Dawa	343,000	457
7	Dessie	270,400	396
8	Jimma	250,900	348
9	Shashemene	208,400	250
10	Bishoftu	207,400	42
Average			388.8

From this the network which can be able to collect as optimum amount as possible would be in between the 300km and 400km is optimum and the number and place that these DC located is also optimum.

To do so, let's see the comparison of the percentage of demand covered at different number of DC in different distance to site.

Table 4-18: Comparison of the percentage of demand covered at different number of DC in different distance to site.

Distance to site in km.	% of demand covered/ to be collected by DC			
	3	4	5	6
100	56.45	61.82	64.62	65.08
200	81.07	87.21	90.98	91.43
300	91.46	96.83	99.54	100.0
400	96.65	98.03	99.54	
500	99.54	100.0	100.0	
600	100.0			

At 300km distance to site, the percentage of demand covered is 91.46%, 96.83%, 99.54% and 100% when 3, 4, 5 and 6DC respectively. At 400km distance to site, the percentage of demand covered is 96.65%, 98.03% and 99.54% when 3, 4, 5 and 6DC respectively.

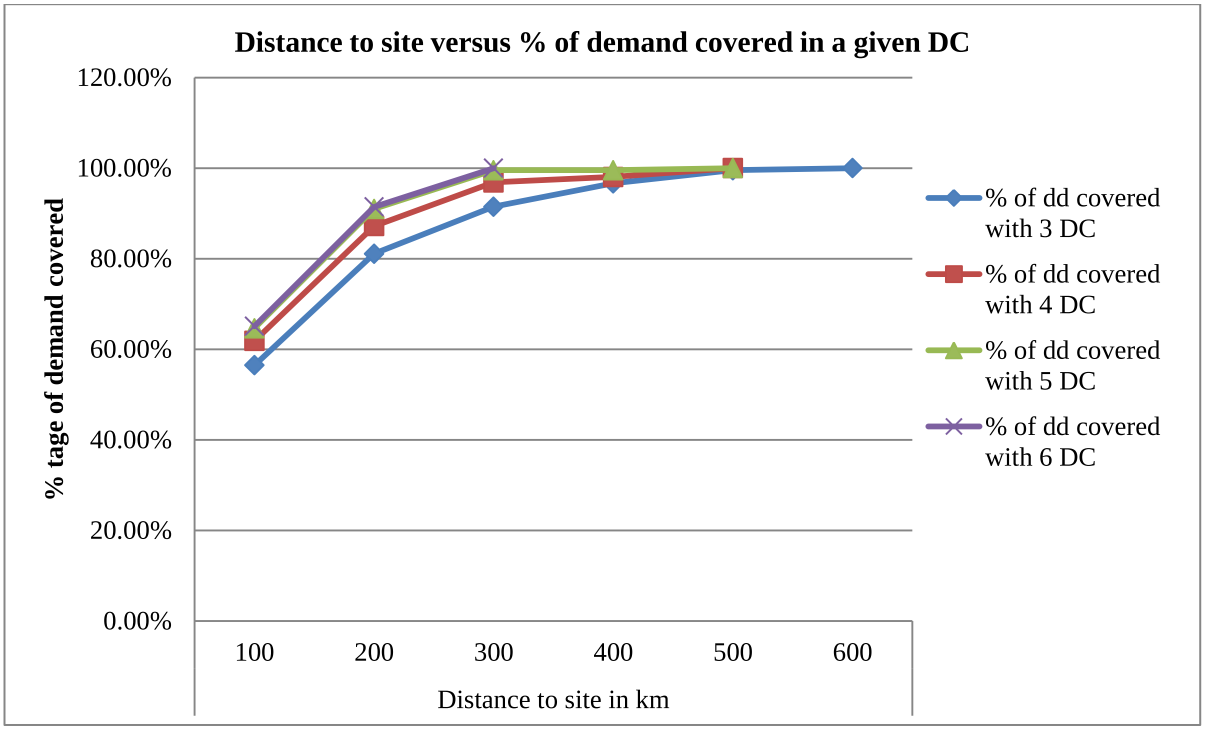


Figure 4-11: Distance to site versus % of demand covered in a given DC

but, since the size of the case product is small and one of the reverse logistics factor which led to the system higher transportation cost as previous study researched, and truck would transport the return product which is end-of-life/use mobile phone under fill or caused more delay, as optimum number of DC with as much closer distance to site supports the collection and can reach the customer better and relatively maximum return be achieved.

The below chart makes more clear and understandable to compare the percentage of demand covered in DC of 3, 4, 5 and 6.

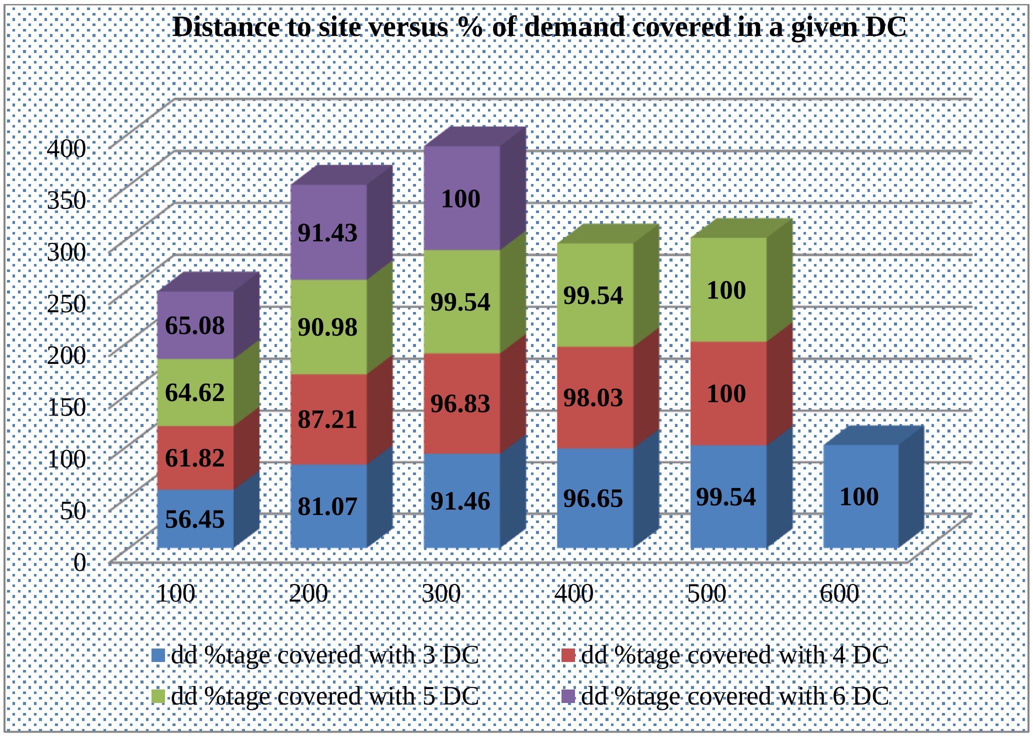


Figure 4-12: Distance to site versus % of demand covered in a given DC

The graph below shows that where the demand covered fully with every DC case, that is, when number of DC is 3, the 100% demand is covered at distance of 600km. But when number of DC is 4 and 5, the 100% demand is covered at distance of 500km, but at 400km and 300km the network with 5 DC covered 99.54% of the demand whereas the network with 4 DC covered 98.035 and 96.83 of the demand respectively, like wise when number of DC is 6, the 100% demand is covered at distance of 300km.

So this gives the decision maker better direction to choose the appropriate number of DC as per their priority.

Taking 5 DC optimal networks, the GFA experiment with 5 DC has the following network:

a) **Product Flow**

Table 4-19: Product flow in 5 DC case

Product Flows

Period

	From	To	Product	Period	Flow, pcs	Distance, km	Flow Cost Estimation, pcs * km
1	...(57)	...(57)	End-of-life/use ...	Time period: 202...	Sum: 8,721,500	Sum: 6,883.69	Sum: 719,376,466.65
2	GFA DC	Burayu Custom...	End-of-life/use...	Time period: 2...	134,200	9.826	1,318,608.264
3	GFA DC	Debre Markos ...	End-of-life/use...	Time period: 2...	265,000	184.488	48,889,260.324
4	GFA DC	Addis Ababa C...	End-of-life/use...	Time period: 2...	1,830,000	0	0
5	GFA DC	Ambo Customer	End-of-life/use...	Time period: 2...	87,600	94.197	8,251,663.664
6	GFA DC	Adama Custo...	End-of-life/use...	Time period: 2...	328,500	78.704	25,854,233.926
7	GFA DC	Debre Birhan C...	End-of-life/use...	Time period: 2...	204,400	116.147	23,740,502.927
8	GFA DC	Welkite Custo...	End-of-life/use...	Time period: 2...	109,500	134.348	14,711,122.902
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The total flow cost estimation with 6883.69km total distance coverage to cover the whole demand is 719,376,466.65km.pcs as it is computed by the total distance covered and total amount of flow.

b) Demand covered by distance

Table 4-20: Demand percentage covered by distance in 5 DC case

Total Demand Coverage by Distance

	Distance to Sit...	Demand, %	Demand, pcs
1	0	20.983	1,830,000
2	100	64.622	5,636,000
3	200	90.977	7,934,600
4	300	99.543	8,681,600
5	400	99.543	8,681,600
6	500	100	8,721,500

As shown at 4 and 5 with distance to site 300km and 400km respectively, the level of demand covered and the amount of flows are equal. Under the average distance between AA to the top ten more populated cities case which is 388.8km the distance to 400km with 5DC, 99.543% demand coverage and 8,681,600 of end-of-life/use mobile phone flow is the optimum.

Therefore:

c) The network looks like in GIS map

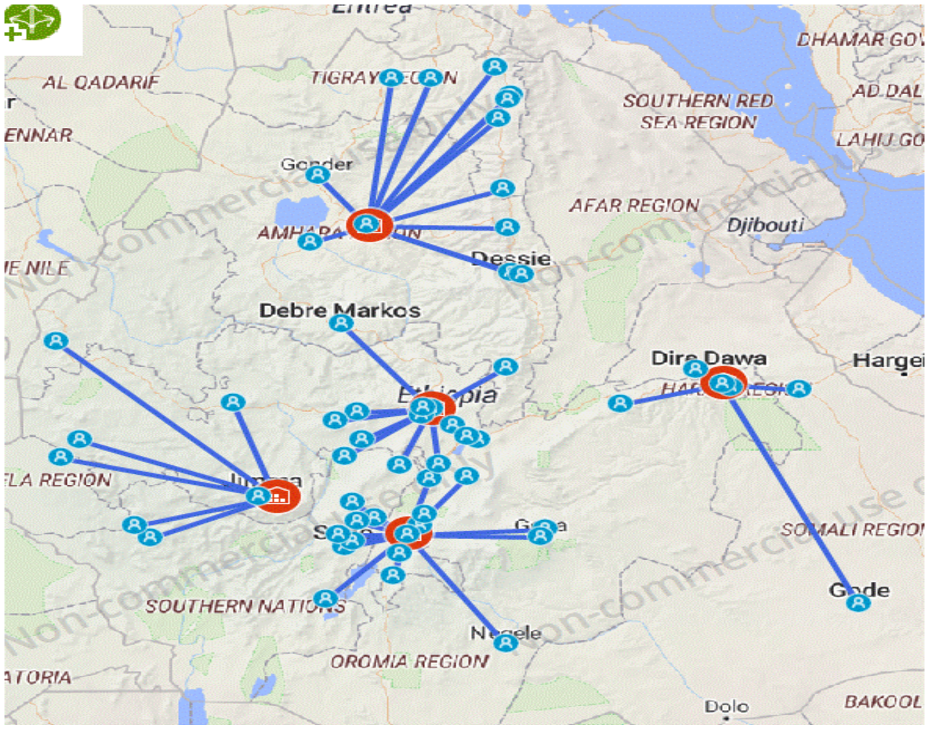


Figure 4-13: The network with 5 DC in GIS map

The network designed above using anyLogistix shows that with 5 DC case and the DCs are located in AA, Debre Tabor, Hawassa, Jimma and Dire Dawa with customer of 14, 13, 17, 7 and 6. So DCs capacity of collection with is 99.54% demand coverage is summerized in the below table.

Table 4-21: Summary of the network

Distribution Center	Number of customers grouped	Collection capacity
GFA AA DC group	14	3,628300
GFA Debre Tabor DC group	13	1791500
GFA Hawassa DC group	17	21677200
GFA Dire Dawa DC group	6	575000
GFA Jimma DC group	7	559500
Total		8,721,500
With 99.543%		8,681,600

So, with this amount of collection at the selected number and location of collection center facility possible to perform in;

1. From the economic point of view, the precious metals of copper, aluminum, silver, palladium and gold can be collected

   A single mobile phone without battery weighs 109gram

   9.17 pieces of returned mobile phone=1kg

Based on the study conducted prior to this research(Singh et al., 2018, 2019), 1kg of mobile phone contains 1666mg of silver, 188.7mg gold, 38.5mg palladium, 427,983mg copper, 12,200.5mg aluminum in short.

So, from the amount collected using the developed network the following materials can be collected;

Silver = (8,681,600/9.17)*1666mg/kg = 1548kg

Gold= (8,681,600/9.17)*188.7mg/kg = 179.47kg

Palladium = (8,681,600/9.17)*38.5mg/kg = 36.62kg

Copper = (8,681,600/9.17)*427,983mg/kg = 407,050.57kg

Aluminum = (8,681,600/9.17)*12200mgkg = 1,160.33kg

2. From the environmental point of view, at least 8,721,500 of mobile phone batteries can be collected assuming that a end-of-life/use mobile phone returned with only one battery. Where 1 battery can pollute 600,000lt of water which is equivalent to 600m^3 (from previous study)

   Which implies 8,721,500 battery*600m^3 water

   = **5232.9million m^3 of water** can be protected from pollution

3. From social point of view, employment opportunity from the collector to top management staff.

4.3 Reverse Logistics Business Model and Incentive Package Adoption

The main focus here is on how the reverse logistics can be effective and the system be sustainable which can support the ever utilization of materials through reducing, reusing, refurbishing, remanufacturing and recycling then finally dispose the unrecoverable in proper way. The model to be selected would be the types of circular economy business model. From the complexity characteristics of reverse logistics network due to its different stakeholders that needs to coordinate along the supply chain either in the forward or reverse flow and its uncertainty in its volume, quality and time of return, one of the types of circular business model, using circular business model canvas is adopted to go through each element.

4.3.1 Reverse logistics business model adoption

Out of the major that is mostly reviewed and agreed up on them by different scholars, in the classification, model, components and sub component, in the electrical and electronics particularly conducted by (Rene et al., 2021; Pollard et al., 2021, 2023; Rosa et al., 2019) the business model canvas with 9 components/elements or blocks are selected to deal with each component in Ethiopian case so that the participants in either generation of this e-waste or regulatory and supportive stakeholders come together for the better implementation of reverse logistics for its sustainability.

Here the researcher interest were how sustainable reverse logistics system be implemented in Ethiopian through shifting the paradigm of traditional linear flow to circular so that the human and environmental problem through either improper recycling and disposal or living together with their enemy, since mobile phone users tend to store their end-of-life/use in their house of different place and even their children have been playing with them, be resolved.

The reason why interested about on both the value capturing and the management is the concerned issue in Ethiopia regarding e-waste management particularly mobile phone related waste management since not yet effectively practiced. The model has three value concepts; value proposition, value creation and delivery and value capturing where under each the nine elements are grouped according to(Rene et al., 2021)

The components/elements under their respective value concept in the 9 element BMC are;

Value creation and delivery

1. **Key partner**

Identifying the key partners by answering the question what are the key partners in the implementation of circular economy in mobile phone product? In general they are government, consumers, and collectors, importers, assembling companies, distributors, retailers and finance aid NGOs.

- Consumers: are who have end-of-life/use mobile phone and consumer of the refurbish mobile phones.
- Government: regulatory bodies authorized to offer license to major participants of collector, transporter, refurbish and recycler and disposer.
- Financing organizations: government, NGO, Associations, donors and professional volunteers.
- Producer of MP: assembling companies and importers.
- Collectors: an individuals, groups or enterprises who are engaged in collecting MP return.

2. **Key resource**

The key resources involved along the sustainable reverse logistics implementation are end-of-life/use mobile phones and the collection points in the location and number is optimized with appropriate collection methods. Better to use more than one method of collection to maximize the amount to be collected. Two of the following methods are recommended to use.

a) Collection centers which are fixed mainly using DC centers permanently as collection centers known to be method of drop off, mini shops dedicated for collection at the place where younger people found and commercial, educational, health and transportation center and residential areas are located. And by organizing campaign or collection events.
b) Pick up; collecting door to door like KORALLE in other SWM method

Facilities or infrastructure at customer, CC/DC, refurbish and recycling site and the others are finance, technology and man power.

The existing computers refurbish and training center is the major/key resource with its available facility is one of the big opportunities to recover mobile phone related e-waste.

3. **Key activities**

The question of “What are the key activities to be done in the implementation of sustainable reverse logistics?

The key activities that the recycling company has to perform are; making decisions on the logistics service by its own or outsourcing trailer with land transport but with the limitation in unreachability or safety outsourced with logistics service providers in air. The collection centers have been running in rental form.

Acquisition, collection, transportation, testing and inspection, storage, refurbishing, recycling and disposal based on the required recovery strategy, distributing the refurbish and sell the recycled product for economic benefit the key activities in reverse logistics.

Awareness creation would be the key activity too for stakeholders involve in the reverse logistics.

The major participant along these key activities to be performed would be the one indicated in key partners in different perspective; in training, operation, managing and financing.

4. **Channels:**

- Dry cargo trailer for transportation of the collected waste mobile phone and component e-waste to the distribution center and then to the refurbishing and recycling site in reverse flow and from recycling and refurbishing site to second market and disposal the non-renewable parts.
- Information and communication and promotion using IT through e-mail, telephone, social media, Google meeting.

Value proposition

1. Customer segment,

What are the customer segments in the supply chain during the implementation of mobile phone sustainable reverse logistics? These are;

- Populated and urbanized cities for potential collection of end-of-life/use mobile phones.
- Potential distributors for refurbish mobile phone.

2. Customer relationship

Good relation between internal and external customers, where the internal customers are workers or employees. But external is end users who have end-of-life/use mobile phones, regulatory bodies, other government supportive organizations, financers and or donors, professional volunteers.

3. Product and or service proposition

Value adding point where capability of technological and potential skills based on required knowledge and experience on particular area of recycling, refurbishing, establishing RLS on both product and service.

Value capturing

4. Cost structure

What type of cost structures has to be used in the implementation of sustainable reverse logistics? These are the major in the area specific case;

- Costs related to collection of end-of-life/use mobile phones to be given to end users in the form of cash either in compensation or purchase bases.
- Transportation cost for transporting collected end-of-life/use MP to the site.
- Refurbishing and recycling cost to recapture value from returned MP.
- Costs related to collection to the collector in amount of collected bases.
- And other administrative costs.

5. Revenue stream: refers the revenue generated from refurbishes MP and recycled material sells.

So, for better communication and understanding which helps through the implementation of MP waste management, detail on what respect stakeholders participate on the system would be necessary.

For more clarity to show the key stakeholders participation on respective responsibility is as illustrated below by adopting the USA practice on e-waste management with major share involvement of Government customize with current Ethiopian practice on plastic waste recycling.

Even if the government on the support and follow up of the implementation of the RL has to takes the loin share, since it is a strategic and political issue especially in developing countries receiving donations from Europe and USA, a detail discussion on the key partners and stakeholder involvement and their responsibility on who is responsible on what helps for what to do and not do for the implementation of effective RL,

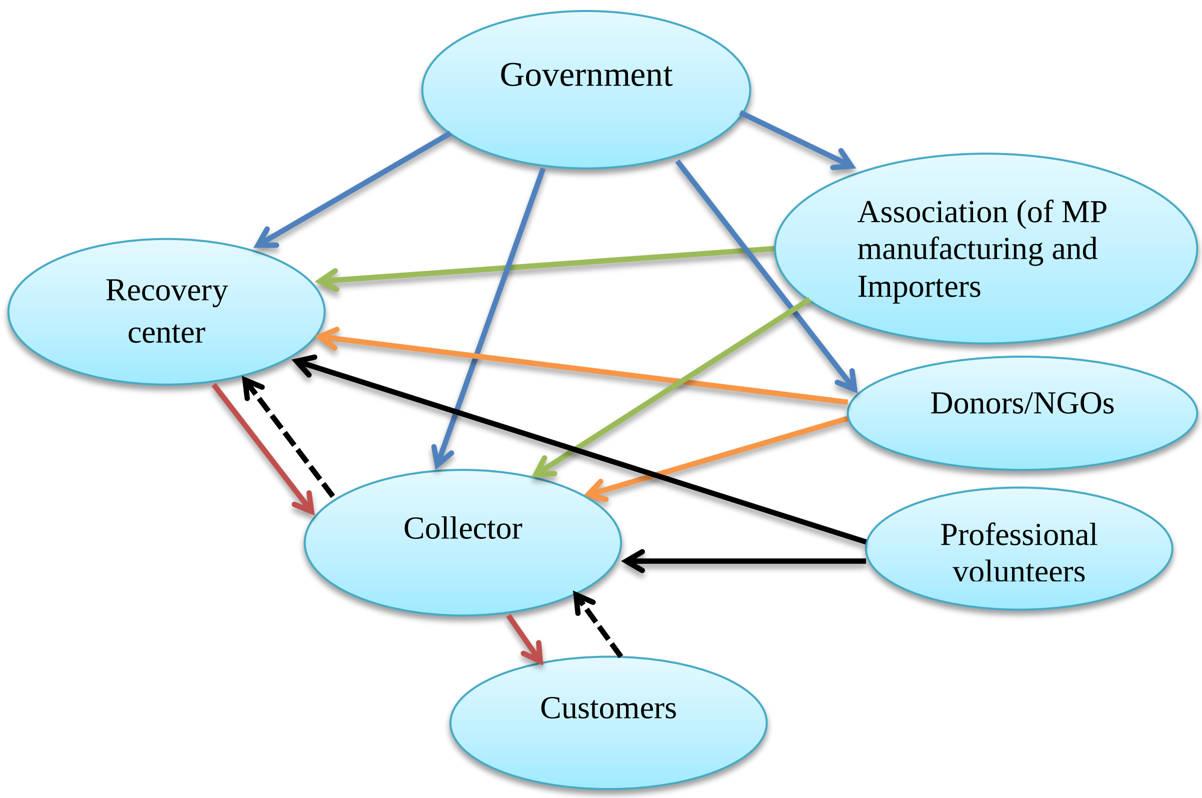


Figure 4-14 model for stakeholder involvement in their responsibility perspective (adopted and customize from (Rene et al., 2021)**and current plastic recycler in Ethiopia(https://www.petcoethiopia.org/)**

Table 4-22: Stakeholders participation in MPW management system.

S.No	Stakeholders	Duties and responsibilities	Responsible body engaged in
1	Government	Collection center place availability	Land management offices
		Awareness creation on e-waste particularly MP waste	Environmental protection offices
		Facilitating collection method in the form of campaign	Environmental protection and media
		To provide existing recycling center with its facility	Ministry of innovation
		Tax incentives for recycler and customer on sell and purchase of recycled material and refurbish MP and also for assembling companies participate in RL	Ministry of Revenue, Ministry of Industry, CBE, Ministry of Trade and Regional Integration and Customs commission
		Export market linkage for recycled material and second market establishment for refurbish MP	Ministry of Industry, Ministry of Trade and Regional Integration, CBE.
		Technical standards adoption related to e-waste transportation, recycling, testing	Ministry of innovation and Ministry of Industry
		Licensing of collectors, transporters, recyclers, storage and exporters and over all data on e-waste in product base.	Respected authorities
2	Association	Financial support	Member of the association
		Training support	
		Facilities used for collection of end-of-life/use MP	
		Standard preparation	
		Administration support	
3	NGOs/international donors	Financial and technical(especially in technology transfer) support	Donors participate in this specific program
4	Professional volunteers	Any support on consulting training, technology adoption, standard preparation	Any volunteer professionals who are in the area of e-waste management

4.3.2 Incentive Package Adoption

In reverse logistics for collection of end-of-life/use mobile phones, customer's willingness plays a vibrant role since they are the one who own the return. The study showed that a huge amount of end-of-use MP found in the customers house(Xu et al., 2016).

One of the things which can improve the willingness of the customer to take-back their return is incentive and it can be given in different forms. And for effective implementation of RL, the key stakeholders participate in the recovery process have to be incentivize.

Incentives directly to the customer who own the end-of-life/use MP, collectors, recyclers, and refurbishers in developing country support the system to be sustainable. Unlike that of the developed country which uses EPR. Just using a pragmatic approach by realizing the current situation of the country, below shows the selected approach of implementing incentives to show the system how could be effective.

For instant, world brand Apple uses a 10% value discount for customer at the time of purchase but in the case of Ethiopia where all the components are imported and not yet involved in R&D a 5% value discount in the form of cash or purchase bases is assumed. In addition Apple offers pre-paid envelop and postage to bring or send customer their return for free. But in Ethiopia case where people access to postal service is low, drop-off and pick up method be better to implement.

In USA a $1 tax reduction for manufacturer/recycler for every 1 WMP recycled is implemented, for Ethiopia case a $5 LC for every recycled WMP be available for their input supply.

According to (Singh et al., 2018) in the precious metal content perspective feature and smart mobile phones have near to same amount, the 5% value discount in the form of cash or purchase bases to the customer and retailers engaged in collecting and supplying end-of-life/use MP. Assuming the average price of the commonly usable smart and feature MPs in the market be used for both. But for collector could be at the bases of the amount collected.

Amount of incentive on value that the customer or retailer can receive = ((17000+1600)/2)*5%

= **450ETB,** since it is an average, depending on the condition that the end-of-life/use MP found the value differs.

CHAPTER FIVE

5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Ethiopia is the second largest populated country in Africa and the first with more than a 25% share in East Africa with a population of more than 120 million with above 50% of the population young which is the active work force of more than 60 million with the age of 18 to 64years old. This show that the prospective number of mobile phone users would be larger, that is why it places at the fifth stage in Africa next to Kenya with 58.54 million subscribers at the beginning of March but it has already exceeds 66 million subscribers at the end of 2022.

This is a huge opportunity of the economic benefit from being environmental and human problem through value recapturing of these end-of-life and end-of-use mobile phones after it ends up its function with proper material recovery. Due to lack of facility in collection, refurbishing and recycling formally in proper way Ethiopia as a country loosing opportunity in her hand. By implementing an appropriate and effective reverse logistics with circularity perspective to gain at most benefit as indicated in this study in safe protecting the environment from pollution and human in danger by collecting as much amount of end-of-life and end-of-use mobile phones that is 8,681,600 by managing in respective recovery process.

5.2 Recommendation

As end-of-life mobile phone become upcoming challenge globally cascaded to country level which is directly related with the development of a country especially in digitalization in the generation as well as in management e-waste together with its mobility with humans, small sized and fast discarding characteristics of it. On the other hand its richest in containing precious metal in the perspective of urban mining view point due to its valuable material concentration special attention on proper recycling has to be given and it should be started in being commented in at most large number of end-of- life mobile phone collection. To do so, the following points are recommended.

1. Government support for refurbishment and recycling plant in providing tax incentives and financial subsidy to motivate them to participate in it so as to prolong the life span of mobile phone for reducing through reusing and repairing and material circulation.
2. Incentive scheme for the collector and recycler.
3. Awareness creation for the society to address information about the impact or e-waste in general and mobile phone waste in particular on the environment and human health
4. Support in facility establishment and awareness creation on secondary market and utilizing refurbish products.
5. Permanent and event based which is drop off type collection modality creation
6. Legislation on responsibility sharing especially on assembling companies and importers to establish private driven e-waste recycling center.
7. Support to conduct a survey particularly in major cities of the country to investigate national MP life time and factors that motivate recovery process.

5.3 Contribution of the Study

The contribution of this research, as waste mobile phone in particular as is the first on product base e-waste management in the country. The study can be used: either for academic research as well as

- As reference for any academic research to be conducted in relation to MP in general and e-waste management as well as reverse logistics network development on electrical/electronic products.
- For MP assembling companies in Ethiopia and their association along establishing recycling centers.
- As a preliminary input to do its detail feasibility study.
- As an input for its optimization research.

5.4 Future research area

1. Optimization of the designed optimal network with optimal collection center has to be done on mobile phone waste.
2. Mobile phone life span in Ethiopia with extensive survey has to be done to investigate the MP life span in Ethiopia which helps to know the exact amount of mobile phone waste available in the country. Because researches conducted on developed and developing country investigates different life spans and off course it is expected that the lest developed country and the country like Ethiopia planning to aligned up with the small medium income developed country by 2025 based on the peoples perspective to wards mobile phone waste, expected to have different life span.
3. Detail feasibility study for WMP recycling on all dimensions needs to be done, that is, on technological, economic, social, environmental and politically feasible.

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Appendix

I. Questionnaire for collecting data from Telecom

1. Number of mobile phone subscribers in regional basis in 2021/22 or 2014 E.C

S.No	Region	City	Number of subscriber	Number of mobile phone in use

2. Growth rate of subscription for four consecutive years

	Budget year			
	2018/19 or (2011 E.C)	2019/21 or (2012 E.C)	2020/21 or (2013 E.C)	20221/22 or (2014 E.C)
Subscriber growth rate				

II. Questionnaire for collecting investment data from Ethiopian Investment Commission

1. Number of investment registered in mobile assembling/manufacturing both FDI and local

List of Investment engaged in mobile phone assembling	Year of registration	Investment period	Investment capital	Investment Type (FDI or Local)

2. Number of investment registered in e-waste recycling company both FDI and local

List of Investment engaged in e-waste recycling company	Year of registration	Investment period	Investment capital	Investment Type (FDI or Local)

III. Format for collecting data from mobile phone assembling companies

1. Electronic waste(e-waste) generated from mobile assembling process

Product Type	Types of e-waste		% share out of the total production on average[1]	Cost % share over a phone on average[2]
	Component level	Parts Level		
Smart phone				
Feature phone				

N.B [1] and [2] four years average(from 2018-2022).

2. Product distribution centers

S.No	Number of product distribution center regionally			% share from total distributed
	Region	City	Qty	

3. Product return before splitting or (2021)

Number of after sales service center			Average amount of phone returned to repair at each center (in pcs.)[3]		Average amount of phone repaired at each center (in pcs.)[4]		Average amount of phone failed to repair at each center (in pcs.)[5]	
Region	City	Qty (in pcs)	Smart	Feature	Smart	Feature	Smart	Feature

N.B [1, 2] and [3] four years average (from 2018-2022).

4. What where the activities being performed to recapture or retain the value of used mobile?
5. How did your company participate on e-waste management?
6. What were the incentives provided from the government on e-waste management?
7. Production History

Product Type	Description	Unit	Budget Year			
			2018/19	2019/20	2020/21	2021/22
Smart phone	Local Production	Pcs				
		Value in birr				
	Export production	Pcs				
		Value in USD				
Feature phone	Local Production	Pcs				
		Value in birr				
	Export production	Pcs				
		Value in USD				

IV. Format for collecting data from Ethiopian Custom Commission

1. Mobile products, components and parts imported both CKD and SKD as well

Description of mobile products, components and parts imported	HS Code 8517.1410, 8517.1310, 8517.1210, 8517.1220 ans 8517.1290	Unit	Budget years			
			2018/19 or (2011E.C)	2019/20 or (2012E.C)	2020/21 or (2013E.C)	2021/22 or (2014E.C)

2. Mobile phone product exported

Description of mobile phone products exported(feature and smart)	HS Code 8517.1290	Unit	Budget years			
			2018/19 or (2011E.C)	2018/19 or (2011E.C)	2018/19 or (2011E.C)	2018/19 or (2011E.C)