Addis Ababa University

Addis Ababa Institute of Technology

School of Mechanical and Industrial Engineering

(Department of Industrial Engineering- Graduate Studies)

A thesis submitted to the School of Graduate Studies of Addis Ababa University

in partial fulfillment of the Degree of Master of Science in Industrial Engineering

Entitled with:

Reverse Logistics Network Design for Lead Recycling Industries from the Spent Lead Acid Battery

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June 2023

Addis Ababa University, Ethiopia

Addis Ababa University

Addis Ababa Institute of Technology

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"Reverse Logistics Network Design for Lead Recycling Industries from the Spent Lead Acid Battery"

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DECLARATION

I hereby declare that the work which is being presented in this thesis entitled ― Reverse Logistics Network Design for Lead Recycling Industries from the Spent Lead Acid Battery is the original work of my own, has not been presented for a degree of any other university and all the resources of materials used for the thesis have been accordingly 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.

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ACKNOWLEDGMENT

My heartfelt passion and gratitude belong to the holy creator God who gave me the power and strength to start and finish the whole part of this study. My appreciation goes to my advisor (Dr. Gezahegn Tesfaye) and my Examiner (Dr. Amha Mulugeta) for their sustained support, effort, and constructive input on idea development. There are also stakeholders to be given many thanks and honors such as some product retailers, distributors, and recycler industry general managers (Aregahegn Gutema) who were welcomed to visit and conduct my preliminary and survey studies on the company they are working in. Most importantly, I wish to thank my loving and supportive wife, Anot Ayele, and my parent, Adanech Eshete and Yemane Zerihun. Lastly, I would like to thank Addis Ababa Institute of Technology (AAiT) staff and administrators for arranging facilities and pre-conditions during the two years of my academic session.

Contents

ABBREVIATION AND ACRONYMS

RLND - Reverse logistics network design

FRLND – Forward and reverse logistics network design

SCM - Supply chain management

LAB - Lead acid battery

RL - Reverse logistics

PLC - Private limited company

ULAB - Used lead acid battery

SLAB - Spent lead acid battery

BTS - Battery storage and transportation

OEMs - Original equipment manufacturers

CLDSC -C loop distribution supply chain

3PRLP - Third-party reverse logistics provider

CLSC – Closed-Loop Supply Chain

ANP - Analytic Network Process

NLAB - New lead acid battery

LTL - Less than load

NO - Network optimization

SIM – Simulation

DC – Distribution Center

A.A – Addis Ababa

D.D – Dire Dawa

Abstract

Logistics network design provides an optimal platform for efficient and effective supply chain management (SCM). Lack of stated roles and activities among the stakeholders and economical reverse logistics network design problems in the industry can cause waste in Ethiopia. Based on the average 3 years battery life service from 2000 GC obtainable vehicles amounting to 1,147,244 data in a country, 382,415 pcs of SLABs are found in 2023. Which is less than 40 percent potential from obtainable spent production. This research aims to develop an economical and profitable reverse logistics network design system for lead recycler industries from spent lead acid batteries. Both primary and secondary data collection sources were used in this study. For secondary sources use manuals, guidelines, different annual reports, and literature relevant to the research, and for primary data sources Surveys and questionnaires, and observation were used to acquire relevant data for the study. Determining the customer demand and the spent product obtainable region, facilities levels, and industry recycling capacity to achieve integrated forward and reverse logistics network design to obtain the least cost design and maximum profit. This study used the framework proposed on network design configuration for reverse logistics based on five significant participants in the network including consumer, maintainer, retailer, collector and distributor, and recycler. The designed reverse logistics model is simulated by integrating the existing using the proposed multi-echelon SIM and validated by using available SLAB data collected in six regional collection centers, using one recycling factory, one supplier, and twenty customers, and simulation used in these experiments. Findings of one-year simulation experiments highlight that the operational performance of profit has been increased from 67,344,439.94 to 76,503,976.32, which shows a substantial improvement in operational performances for the finances compared to the existing network, particularly in: Facility cost, Inventory cost, and Transportation Cost. The identified existing facilities will guarantee enhanced cost-effectiveness of distribution operations with potential cost savings in transportation and warehousing without additional charge for the activities to back the spent products when measured via simulation.

Keywords: Integrated reverse logistics, network design, anyLogestix, Lead-acid Battery, collector and distributors, and, roles and activities.

Chapter One

Introduction and Justification

1.1. Introduction

Reverse logistics is to take back the used products, either under warranty, at the end of use, or the end of the lease, so that the products or parts are appropriately disposed of, recycled, reused, or remanufactured (Jayant, 2015). The Terms like Reverse Channels or Reverse Flow already appeared in the scientific literature of the seventies but were consistently related to recycling in 1974 and 1978, and the Council of Logistics Management (CLM) published the first known definition of Reverse Logistics in the early nineties 1992 (M. P. De Brito & Dekker 2018). Concept of reverse logistics, most of the so-called, environmental regulations -which have been passed in a growing manner, in recent years and many parts of the world- usually mention some objectives to be reached in certain periods (being perhaps the most common one, recycling targets) (Quesada, 2003). De Brito & Dekker (2004) stated that reverse logistics can be used for various purposes such as repairs, refurbishing, remanufacturing, recycling, and so on.

A reverse supply chain focuses on the backward flow of materials from the customer to the mainstream of business (or alternate disposition) with the goals of maximizing value from the returned item or minimizing the total reverse logistics cost and a forward supply chain is a network of facilities and distribution options that performs the functions of procurement of materials, the transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers (Jayant et al., 2014a). Reverse distribution can occur through the original forward channel or combinations of both forward and reverse channels.

Reverse logistics is ‘the process of planning, implementing and controlling backward flows of raw materials, in process inventory, packaging, and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal (Rubio et al., 2008). Used lead acid batteries depending on their nature, sales volume, and distribution channel, the reverse logistics can be organized and designed into a system for collection, sorting and inspecting, repairs and refurbishing, recycling and waste disposal, and redistribution. Therefore, a conceptual framework with the definition of the processes that constitute an RL system becomes an essential tool for this understanding. This type of research is important because the distribution of lead acid battery products made from hazardous substances increases over time and the small amount collected after use increases.

To overcome this issue, it is necessary to set up a recycling facility for rising goods flow from end users to the recycler. This paper studied the reverse logistics network design (RLND) problem of the spent lead acid battery (SLAB) recyclers industries, which involves transportation, warehousing, locations, distributions, and collection process of logistics network design by determining the existing and selected numbers, places, and capacities of facilities and the quantity of the flow between them. It has been explored for all stakeholders in the sector including battery distributors, repairers, recyclers, customers, and environmental protection agencies to help implement the logistics network along with their roles and activities. Additionally, it answers questions such as where to source raw materials and how to collect, store, and transport that material, products, warehousing, inventories, and optimal network configuration design.

In most of the past research, the design of forward and reverse logistics networks is considered separately which may lead to sub-optimal design, and the recent researcher believes the fact that the configuration of the reverse logistics network has a strong influence on the forward logistics network and vice versa; designing the forward and reverse logistics should be integrated (Khajavi et al., 2011). The existing models handle forward and reverse flows simultaneously for manufacturers of the original product however in addition to simultaneous activities main differences of this research using integrated reverse logistics network design into the current transportation, facility, and inventory carrying.

Finally, the design can be adapted to different problems, which will be of great value in large-scale industries and society, and it can identify issues and create result-oriented outcomes. To achieve this, firstly, the researcher used SPSS frequency analyzer for the improvement and sustaining the action of the roles and activities of stakeholders. Secondly, developed the minimum cost of reverse logistics network design and maximum profit of financial statement by using anyLogestix simulation software.

1.2. Problem Statement

Traditionally, organizations have focused on improving their forward logistics activities; most have not treated the reverse logistics process with the same care and diligence afforded to traditional areas of logistics (Badenhorst, 2013). Janse et al., (2010) explained firms have adopted the RL practices either to achieve the economic benefits which are inborn in the competitive advantage or forced by the governmental legislations and environmental awareness of the public.

In Ethiopian there are no RL practices monitoring mechanisms on ways of dumping the replaced acid solution and/or the old secondary accumulators and no education is offered to the workers nor effective collection system for spent batteries is available (Duressa & Fite Duressa, 2008). Schaddelee-Scholten & Tempowski, (2017) improper lead acid battery recycling presents a significant environmental and health problem in a country. Therefore, sprinkling battery acid into the environment, dispersing spent LAB, and recycling plants lacking up-to-date technology are common practices. This violates the right to a clean, healthy, and sustainable environment as recognized and protected under Article 1 of the Ethiopian Constitution 1994.

The recycling industry exists based on the obtainability of the spent product (finished its service) in a country from the number of vehicles amount. When we compare the SLAB available from the obtainable vehicle number in a country from the recycled amount and the export number of spent products from the customs information, those collectors do not efficiently collect the rest of the amount. For example, according to the Ministry of Transport Department of the Information Communication Technology Bureau, the number of vehicles available data in Ethiopia reached 1,401,114 in 2022, and average increase 126,935 thousand from 2018-2022 years showing an. Microgeneration scenarios with suitable battery sizes are found to have lifetimes of 2 – 4 years for high production (Jenkins et al., 2008). Based on the average 3 years of battery life service from 2000 obtainable vehicles amount 1,147,244 data, 382,415 pcs SLABs are found in 2023. However, industries can collect 27,150 spent products from 2023 on average, and from different collectors such as scrape dealers, battery maintainers, automotive garages, and distributor/retailer exporters collected and exported 125,676 within 2023 as per custom data. The sum of the recycled amount by industry and from export, which is less than 40 percent potential from obtainable spent production. In addition to the export of the spent product, there is no responsible person(collector) to take back these hazardous spent products (reverse logistics network design), and the unavailability of an effective collection system for spent batteries in a country, these are forced recycling industries to shortage of raw materials.

Lack of stated roles and activities among the stakeholders and economical reverse logistics network design problems in the industry can be collection network, network configuration, transportation, warehouse, inventory, and logistics design are mean Couse of SLAB waste problem in Ethiopia. The area of reverse logistics (RL) has recently received considerable attention, due to a combination of environmental, economic, and social factors (Alshamsi & Diabat, 2015). Network integration such as collection and distribution, transportation sharing, warehousing, and other logistics activities can reduce network complexity and help to find solutions. The researcher recalls SPSS for analysis of the frequency and develops guidelines for the roles and activities of all stakeholders for the sustainability of improvement action and anyLogestix PLE tools for the solution of the simulation network problem.

1.3. Research Question

i. What are the existing reverse logistics network design situation of recycling, collection and distribution, storage and transportation, information sharing, and others for the spent lead-acid batteries?
ii. What roles and activities can be expected in the reverse logistics network design concerning the sustaining actions of all stakeholders regarding environmental, social, and economic?
iii. How can a cost-effective reverse logistics network be designed for the spent lead-acid batteries?

1.4. Objective

1.4.1. General Objective

The main objective of this research is to develop an economical and profitable reverse logistics network design system for lead recycler industries from spent lead acid batteries.

1.4.2. Specific Objectives

i. To assess the existing situation of lead acid batteries reverse logistics network design in Ethiopia.
ii. To assess the roles and activities expected in the reverse logistics network design for used LAB.
iii. To develop integrated cost-effective reverse logistics network with existing forward logistics network

1.5. Scope and Limitations

This study due to the constraint of time selected one supplier of raw material based on the most importer available area, based on the most populated and obtainability of vehicles in the region and geographical area selected six LAB distributers and twenty consumers of Addis Ababa city and based on capacity one recycler industry is selected.

The following areas when building a robust network design in reverse logistics: collection and distribution network design, inspection/sorting, pre-processing and logistics, inventory, social and environmental issues, Procurement costs and processes, and information technology systems to name a few. Identify roles and activities; a network design will determine the current status.

Transportation and logistics

This drives the whole reveres and supply and determines the proper running of operational procedures. Route planning and optimizing logistics support the systematic and timely transportation of goods.

Collection and distribution centers

This involves selecting and placing the correct reverse and supply network node locations. This included determining the location and facilities required to build a strong and efficient supply chain network. The size of the warehouses, determining the best opportunities for finding scrap, and developing collection routes and distribution centers should also be defined according to the need.

Inventory and warehouse

This will prove to be one of the trickiest areas while planning and management of inventory and warehouse that needs to be stored and transported should be identified. This also includes planning satisfaction time and the response time that needs to be constant.

Procurement costs and processes

Sourcing of raw materials collection in terms of cost, time, and location, and the number and quality of collectors, manufacturers, suppliers, and distributor needs to be identified.

Network design that is founded on a fact-based quantitative analysis with a review of processes, technology, and people that: ensure alignment with the overall business environment and growth strategy to minimize costs and achieve desired service levels and analyze alternative processes collection and distribution, warehouses and inventory, transportation and procurement costs, and processes.

- The following point are not in the scope of the current research
    - Other expenses are those that are non-operating and do not relate to the main business operations including interests, sales of assets, impairments, and ...
    - Managing carriers, damage incurred in transit, one-off shipments, tracking—or attempting to track due to poor returns processing service levels, traffic, manpower, and custom duty in the calculations.

The main limitations of the study are due to the restriction of time researcher's inability to contact all partnerships (Consumer, collector, distributor, maintainer, government sector, and recycler industry). However, the study will suggest possibilities for future research including contacting others, expanding the sample size, and ensuring that the reverse logistics network design successfully copes with overall partnership beneficiaries.

1.6. Significance

Reverse logistics network design helps enterprises to simulate and visualize their reverse logistics to optimize them. Most company due to network design problems business areas are impacted. Designing an optimal integrated RLN will be able to meet the long-term objectives of the company.

Once the path is determined and the design has been completed in a good way, the business will bring many substantial benefits.

Chapter Two

Literature Review

2.1.Introduction

Reverse logistics start at the end consumer, moving backward through the supply chain to the distributor or from the distributor to the manufacturer (de Brito & Dekker, 2004). Kocabasoglu et al., (2007) explained the importance of a reverse supply chain (RSC) can potentially reduce negative environmental impacts by capturing and exploiting used and waste disposal products and possibly extracting virgin raw materials. Therefore, this literature focused on RLND on areas of problems as follows:

- The process of reverse logistics network design (RLND) of the industry
- Roles and activities of stakeholders
- The research gaps
- Conceptualize reverse logistics network design.

2.2.The Process of RLND in Industry

Based on the process of reverse logistics network design in the industry aspects five critical activities are identified as follows.

2.2. 1 Collecting, Sorting, and Pre-processing

At the end of the product, to collect the spent product efficiently a structured reverse logistic network is required for product recovery which encompasses reuse, remanufacturing, and materials recycling (Jayant et al., 2014b). Ayvaz et al., (2015) propose a generic reverse logistics network design model under return quantity, sorting ratio (quality), and transportation cost uncertainties. However, several risks and uncertainties are associated with EOL recycling. These are related to timing, quality, quantity, and variety of collection rates and times; estimation of operation and cost-related parameters for reverse logistics networks; decisions about a resolution for recycling, and cost of coordination. Based on the lifetime of LAB, can determine available scrap amount and collection rates, transfer time, transfer cost, and resource utilization predictably. The effect of the RLND process simulation was done for the spent batteries.

Zaarour et al., (2006) are addressed the problem of determining the number and location of centralized return centers (i.e., reverse consolidation points) where returned products from retailers or end customers were collected, sorted, and consolidated into a large shipment destined for manufacturers' or distributors' repair facilities. Inspection/ Sorting is the next stage which may be carried out either at the point/ time of collection itself or afterward at collection points or rework facilities (Samir K Srivastava, 2012). Collected items generally need sorting in some kind of order to preprocess and store-processing may be in the form of sorting, segregation, partial or complete disassembly, or minor repair and refurbishing activities (Oliveira et al., 2012).

Therefore, it is carried out depending upon the technological and economic factors after inspection/sorting and pre-processing either at collection centers for storing to transporting purposes as spent batteries to the recycler industry or at minor repair and refurbishing activities or rework and back to consumers after maintaining as used good.

2.2.2. Distribution

According to Tasan & Gen, (2012), simultaneous pick-up and deliveries, which considers simultaneous distribution and collection of goods to/from customers, is an extension of the capacitated vehicle routing problem. J. Zhang et al., (2016) lead-acid batteries consist of electrolytes, lead, lead alloy grids, lead paste, and organic and plastic materials that contain many toxic, hazardous, and flammable sources of danger. Battery rescue uses safe battery storage and transportation container of waste / used lead acid batteries to provide a safer, more convenient service while also reducing the environmental impact of batteries (Rescue & Transport, 2022).

Designing effective and efficient RL networks is a prerequisite for maintenance and remanufacturing and a key driver for delivering economic benefits (Srivastava, 2008). As observed, the majority of spent products are not recycled, and some of them become part of the household waste in Ethiopia. This is due to many reasons, including the lack of government policies to encourage the returned battery for recycling, lack of proper collection by distributors and maintainers, and dearth of awareness by the user as its elements are a hazardous waste as well as unenlightened of its influence on environmental, social, and, economic.

Spent and new lead acid batteries are sets of the same size and shape. It’s easy for simultaneous distribution and collection that arises when the distribution of goods from a depot to a set of customers and the collection of waste from the customers to the depot can be performed by simultaneously.

2.2.3. Inventory and Warehouse

Previous researchers have developed ways of managing forward-oriented supply chains and given insight to solve single-stage inventory systems (Chung et al., 2008). Blackburn et al., (2004) in the reverse material flow, the used products are returned, remanufactured, and shipped to the retailer for resale. Chung et al., (2008) use an inventory system with the traditional forward-oriented material flow as well as a reverse material flow supply chain. Different researchers are rare to put a way of sharing the same warehousing of the hazardous material like new and spent lead acid batteries. Battery storage and transportation (BTS) container, of waste / used lead acid batteries to provide a safer service while also reducing the environmental impact of batteries (Rescue & Transport, 2022).

The self-discharge reactions limit the shelf life of the lead/acid battery (Bullock, 1994). To this order on demand inventory system for remanufacturing and recycling is proposed. This closed-loop supply chain warehouse system can maximize the joint profits of the distributor and collector, the manufacturer, the third-party recycle dealer, and the retailer.

2.2.4. Battery Recycling

Developed an RL network for battery recycling, a system with a reward and punishment mechanism to solve the problem of recycling end-of-life, from the end customer to the remanufacturing process with the perspectives of environment and transportation costs (Hao et al., 2021). Upon arrival at the recycling facility, the spent batteries process is followed by pre-treating broken/crushed components, Smelting, and refining the lead, washing then shredding or melting the plastic components, and Purification and treatment of the sulfuric acid electrolyte (Pan et al., 2019).

Paszek et al., (2012) states that recycling waste is a priority in waste management, and, when impossible, disposal, with the lowest possible harm to the environment is recommended. The pre-treatment is comprised of breaking the batteries and separating the battery components (Neiström, 2018). Jolly & Rhin, (1994) explain lead recycling industry has also become a net producer of recycled plastic: the first European producer of recycled polypropylene by washing then shredding or melting from lead-acid batteries whose consumption as battery boxes and the second step of the process is to melt and reduce lead compounds into metal, and then to refine this metal for new applications, like batteries.

2.2.5. Information Technology Systems

A key element in reducing uncertainties in the different stages of the reverse channel of a supply chain is access to accurate and timely information on the status, location, and condition of products moving about in the supply chain (Jayaraman et al., 2008). Information technology and collaboration activities supporting both the forward flow of goods from the manufacturer to the consumer and the reverse flow from the consumer to the manufacturer can mitigate many of the problems and deficiencies.

2.3. Stakeholders' Roles and Activities on the RLND

A stakeholder can be described as a person or group (within or outside an organization) who can influence or be influenced by the organization's activities (Afum et al., 2019). A reverse logistics network usually consists of four levels: customers, collection centers, treatment plants, and markets (X. Zhang et al., 2022). It consists of identifying the different roles in an RLND, activities per role, the requirements for these activities, and the performance indicators per requirement per activity. A reverse logistics (RL) system will be essential to increase the product recovery rate and support the recovery, reuse, remanufacturing/renovation, and proper disposal of products and their components (Trevisan et al., 2021). Reverse logistics network activities depend on the interaction between different stakeholders to properly collect and recycle SLAB. Researchers found from questionary and observation that consumer lack of understanding of this hazardous material, lack of effective government regulation, distribution and collection systems, and recycling technologies are major barriers and challenges to solving the problems. Therefore, all stakeholder must sustain their roles and activities on these hazardous substances as stated below:

2.3.1. Consumer

Reverse logistics starts with the end user or consumer moving back through the supply chain to the distributor or from the distributor to the manufacturer (Jayaraman et al., 2008). Reverse logistics can also include processes where the end consumer is responsible for the final disposal of the product, including recycling, refurbishing, or resale (Taylor et al., 2010). Reverse logistics is the process would like to return or recycle products or goods that have been returned to the company by the customer. Moreover, a company has full control over a product's life from start to end involving decisions relating to recycling, warranty, disposal of discarded products, etc.

Used lead-acid batteries have a complex composition with various components made of lead, metal, oxide or sulfate, and plastic and electrolytes (Neiström, 2018). Heavy metals are considered potent pollutants and among them, lead is categorized as one of the top pollutants all over the world (Varshney et al., 2019). According to the Ethiopian hazardous waste management and disposal control proclamation lead, Lead compound, and acid solution are within the categories of hazardous waste. As observation problems, are especially serious in Ethiopia due to the lack of regulations and stakeholder awareness about spent lead-acid batteries. Because lead is toxic to the environment and to humans, recycling and management of spent lead-acid batteries have become a significant challenge and are capturing much public attention (Li et al., 2016). Thus, recycling spent LABs by collecting from consumers is beneficial in improving environmental and socioeconomic sustainability.

How do Consumers Free of SLAB?

With the integrated RLND retailers are required to accept a defective lead-acid battery with or without purchase when a customer purchases a new one. Companies that are mass generators should also take their end-of-life lead-acid batteries to a collection point or recycler company. The public and mass generators should take their lead-acid batteries to a collection point. It is illegal to dispose of or attempt to dispose of a lead-acid battery on any surface, including landfills, lakes, streams, or among others. Leaving lead acid batteries on the streets and in parking lots or landfills is illegal hazardous waste disposal and can be prosecuted under the laws of the country. If you plan to do anything other than recycle these batteries, they need to be treated and managed as hazardous waste according to national law.

2.3.2. Repair Shop

According to investigations of the Lead Recycling Africa Project, in Ethiopia's capital, Addis Ababa, a large number of small workshops are engaged in the reconditioning of used lead-acid batteries (Schaddelee-Scholten & Tempowski, 2017). The workshop owners buy used batteries, replace the sulfuric acid, and – depending on the quality of the battery – conduct additional repairs such as exchanging damaged lead electrodes. Most individuals in these repair shops depend on this work for their livelihood. Generally, the level of awareness of the risks of lead poisoning among repair shop owners and workers was found to be very low: The operations are mostly carried out in the immediate surroundings of their residential homes. Such settings bear the risk that the workers' families and other community members are exposed to high lead contaminations, particularly, because none of the workshops have an adequate solid or liquid waste management system.

The repairing workshop must follow the roles of the proper and adequate management of the installation and operation of hazardous waste facilities by state regulations, the Pollution Prevention Act, and the installation of a hazardous waste management plan.

2.3.3. Retailer

The selling and collection chain cycle are essential to bringing the spent materials to their correct end-of-life destination. Battery retailers are responsible for distributing new LAB as soon as collecting and storing used products. Vehicles older than 50 years or end of life and uncollected used batteries are likely to be collected from scrap dealers and garages, so they should be delivered to battery dealers with due care.

What are the Rules about Collecting and Storing Spent Batteries?

In the Observation in Ethiopia, there is no responsible body to collect and dispose of the spent product, before they are broken and dismantled in the recycling industry, the liquid acid wastes are disposed of where they are found. This results in highly contaminated soil, groundwater, and other contaminants in areas where the acid is released (Evanko et al., 1997). Collectors should be careful in the way they store batteries before sending them for recycling. Undamaged batteries should be stored upright in a covered pallet, wrapped area (or device), sealed, and hidden to prevent any acid from entering the environment (Schaddelee-Scholten & Tempowski, 2017). Additional environmental requirements or battery storage recommendations and regulations developed by the Hazardous Waste Agency can reduce environmental pollution.

Misuses and high temperatures during the operations may result in cell cracks and release hazardous liquids and gasses (Schismenos et al., 2021). To prevent fire ignition and human and environmental impact strict safety regulations in the battery storage area should be followed. The damaged batteries" are batteries that are cracked, broken, or missing one or more caps (Box, 1995). Collectors should store used batteries in non-reactive, structurally safe, and closed containers such as (BTS) containers specifically for safe, environmentally sustainable storage (Rescue & Transport, 2022).

Battery storage consists in storing new equipment and waste to be recycled. Lead acid batteries that have finished their service or are newly stored cannot generate any heat. Stored batteries must be in a cool, well-ventilated area away from ignition sources (e.g., welding, smoking) because high ambient temperatures will shorten the storage life of all lead-acid batteries (Safety, 2016). Exploded lead acid batteries should be stored in separate battery compartments. Such rooms must be physically separated from other areas, devoid of localized heat sources, and have doors and/or partitions designed to meet the required fire-resistance rating for the application.

Hailu, (2019) warehouses are used for receiving, storing, order picking, and shipping goods and is use FIFO (first-in, first-out) is important because batteries do have a shelf life, and periodically cleaning and recharging batteries because they naturally lose their charge over time. Customer orders are picked, packed, and shipped based on their needs, and orders are sent out within the required timeframe (J. Zhang, Wang, et al., 2016). Responsible battery management is necessary to ensure that the environment remains unaffected and that battery materials can be recycled endlessly into brand-new batteries.

2.3.4. Regional Collector

In the case of the company mainly considered to primarily focus efforts on improving the existing collection and recycling system rather than building up parallel collection infrastructure (Manhart et al., 2018). As the distribution and use of lead acid battery materials are increasing in quantity, they are easily available in the market from retailers, and these materials are misused and disposed of improperly at the end of their service life. Guidelines on the distribution and monitoring of LAB materials are important in efforts to prevent misuse and disposal.

Distributors are legal entities separate from their manufacturer owners and have many of the same rights and obligations as individuals and groups. The company is a licensed industrial and commercial company that produces Lead Ingot and LAB (Hazardous Materials) in the country. Producer of lead ingot and lead acid batteries is a company recycling these hazardous materials domestically and having an industrial business license. Various registered lead acid battery importers and non-manufacturers, owners of general importers, and acting as distributors of imported batteries for the company, are thus consumers. There are lead acid battery importers who are recognized by the Ministry of Commerce and are allowed to import lead acid batteries intended only for their own production needs. Registered lead acid battery distributors are organizations that have a domestic trade license from the Ministry of Commerce to distribute directly to consumers or through licensed retailers. At the end of their service, the end users of lead acid batteries are companies that process them as raw materials, change their physical and chemical properties and add value to them, which are licensed by the licensing institution and use the end-of-life batteries for their intended use.

Monitoring is a test function to monitor the distribution of lead-acid batteries (Zezhong et al., 2010). The test team is a team that examines the integrity and existence of packaging sites and locations maintained by a registered distributor to process lead acid battery distribution. A Safety Data Sheet is a sheet containing information on a lead acid battery regarding physical, and chemical properties, potential hazards, handling methods, and special measures in case of an emergency (Drive, 2017). Labeling in the form of pictures, text, or both, information on the lead acid battery or about the operator of the product, and other information must be placed in it by the applicable laws related to the product (Byrne, 2010). The environmental protection authority appoints an Administrator to administer these regulations.

2.3.5. Recycler

Current networks and processes related to the return flow of vehicle batteries are not well established, nor well-defined governmental pressure forces automotive manufacturers to set up creating an urgency to develop efficient collection networks (Prevolnik & Ziemba, 2019). The amount of waste lead-acid batteries has increased and pollution caused by this waste has also significantly increased. In addition, the effective management and development of the LAB-recycling sector are significantly challenging because of the presence of no regulated informal recycling. However, rates of lead exposure and release are highly controlled and regulated in developed countries, these rates are considerably higher in low- to medium-income countries (Tan et al., 2019). Upon arrival at the recycling facility, the spent batteries process is followed by pre-treating broken/crushed components, Smelting, and refining the lead, washing then shredding or melting the plastic components, and Purification and treatment of the sulfuric acid electrolyte (Pan et al., 2019).

Apart from the one major industry involved with the lead/acid batteries treatment, there is a plethora of small smelters in Ethiopia, which operate without conforming to the basic rules instituted by the law, against the uncontrolled polluting of air and ground. Taking into account the known companies and hazardous waste laws, applicable technology needs to be implemented by the guidelines issued by the legislators. In Ethiopia, the Ministry of Environmental Protection should focus on public and government awareness of issues related to battery recycling and create awareness by working with consumers, collectors, and recyclers. For the previously mentioned reasons, it seems important to improve battery recycling in Ethiopia, implement effective collection methods, and update the current technology. For the previously mentioned reasons, it seems important to improve battery recycling in Ethiopia, implement effective collection methods, and update the current technology.

2.3.6. Partnerships and Collaboration Design

Partnerships and collaboration design are decisive for developing a collection system and recycling solutions for waste batteries (Manhart et al., 2018). The following points climax aspects that should be considered by governments and other environmental regulations when developing strategies for sound end-of-life management on the existing distribution chain:

Lead-acid batteries are already collected and recycled in many world regions because of their high, intrinsic economic value, which is relatively easy to exploit, also with rudimental and polluting recycling processes (Hat, 2022). In contrast, there is a lack of a structured, economic, or environmentally sound collection design system based on existing market incentives on the spent LAB.

Governments and other environmental regulatory bodies should also design national waste management policies aimed at mounting pressure on manufacturing firms to comply and adopt RL into their operations (Afum et al., 2021). The environmental protection authority is required to audit the distribution of importers and domestic products to ensure that the imported and produced battery that can be collected as per the distribution of products and implemented as per the roles and activities of stakeholders. A researcher proposed a generic management chain for waste lead-acid batteries is given in Figure 2-1. Energy access projects may support improvements by working with recycler companies and distributors to build up sound collections and by supporting national environmental authorities.

As a general rule, a collection system should have a kind of volume-based target. Company-based benchmarks should be derived from the manufactured and imported number of batteries brought onto the market in a defined time period or based on distribution of LAB and average lifetime of service can estimate the waste being generated in the country.

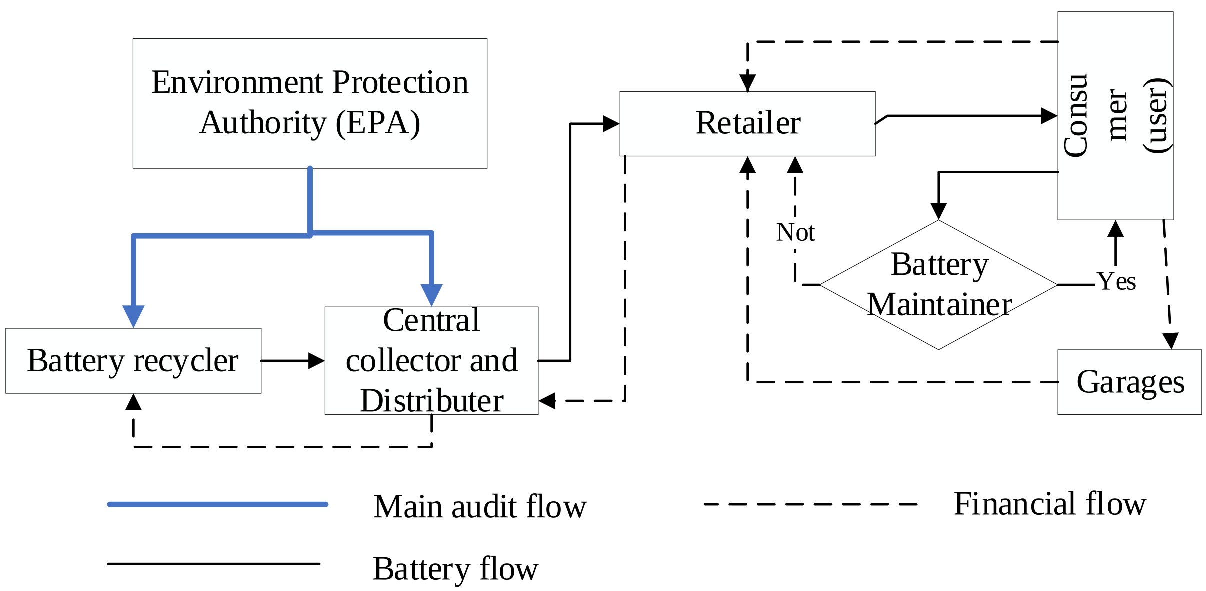


Fig 2.1: Generic proposed management chain for used lead acid battery source:Manhart et al., 2018

2.4. Research Gap on Reverse Logistics Network Design

Srivastava (2008) developed a conceptual design for simultaneous location–allocation of facilities for a cost-effective and efficient reverse logistics (RL) network to cover costs and operations across a wide domain, and researcher proposed a reverse logistics network consisting of collection centers and two types of rework facilities set up by the original equipment manufacturers (OEMs) or they're a combination of specific product returns under various strategic, operational and customer service constraints in the Indian context. Sasikumar & Haq (2011) is designed and integrated a multi-echelon, multi-product closed loop distribution supply chain (CLDSC) network with the best third-party reverse logistics provider (3PRLP) process to achieve cost efficiency and delivery schedules in reverse logistics for recycled lead a costly commodity. Also, Dolnicar et al. (2015) developed a multi-objective, multi-echelon, multi-product strategic planning model for a lead/acid battery CLSC, in this model, minimization of the total CLSC costs and the maximization of the total demand for the collection of returned batteries covered by the collection centers and hybrid facilities are addressed as the objective functions. The proposed model LINGO 8.0 provides solutions related to optimizing and planning the number of facilities to be opened, their location, and the allocation of their production flow.

Kaya & Urek (2016) developed mixed Integer Off-Line Solution Optimization of facilities locations, inventory volume, cost of new products, and overall supply chain profitability incentive cost to collect the right product by applying a reverse logistics system to remanufacture ULAB products in a low production environment. They determine and analyze the structure of optimal policies and find that in many realistic scenarios (Rubio & Corominas, 2008). Kannan et al. (2009) use a multi-criteria decision-making tool for problems related to options for ULAB batteries. They develop an Analytic Network Process (ANP) based decision model using a balanced scorecard approach that solves the problem involved in the system.

Louwers et al. (1999) explain detailed during the preparation of the facility, and the operating costs related to energy, labor, maintenance, and utilities are included in the proposed allocation model for the collection, processing, and redistribution of carpet waste. Location and Distribution (Network Design) is the most important and critical area of RL that is assuming greater importance day by day. In many cases, recovery networks are not developed independently "from scratch", but are linked to existing logistics structures, especially if products are recycled through original equipment manufacturers, this is true. The location and configuration of facilities often influence and affect the external natural environment, mainly because return goods are expected to maintain the roles and activities of stakeholders and use reverse logistics network design to follow environmentally friendly and cost-effective processes. The first category of risk which influences the supply chain design and management concern is uncertainty embedded in the model parameters, which affects the problem of balancing supply and demand (Hatefi & Jolai, 2014). All collected and recycled products are comparable to the distribution of new products, and Those uncertainties are reduced if the distributor is responsible for exchanging a new battery for a lost product and sending it to the industries. Some other key challenges are related to integrating product design and operationalizing implementation plans for RL to design efficient RL networks. This challenge is also minimized by designing reverse logistics (RL) networks to collect used products and then carry out processing and recycling activities. Due to the stringent pressures from environmental regulations companies and stakeholders have been confronted with the challenge of designing RLN.

Based on an IBM Montpellier case study, by Keh et al. (2012) the reverse logistics model allows companies to meet three main objectives, which are (1) providing economic opportunities by reselling or recycling machines and parts, (2) complying with laws such as waste management and successfully addressing environmental challenges, and (3) creating local businesses in terms of achieving important social challenges. Environmental and social drivers can quickly emerge from a reverse logistics project (Keh et al., 2012). RL networks are not established independently 'from scratch' but are linked to existing logistics structures (Srivastava, 2008). This is especially true for organizations that recycle original equipment manufacturer (OEM) products.

This study used the framework proposed on network design configuration for reverse logistics based on five major participants in the network including consumer, maintainer, retailer, collector and distributor, and recycler. Researchers face two main challenges in reverse logistics network design: (1) how do you manage the roles and activities of all stakeholders? And (2) how do you integrate these hazardous used material collection logistics activities into forward distribution logistics networks?

The current models handle forward and reverse flows simultaneously however in addition to simultaneous activities the researcher's contribution is to develop an integrated reverse logistics network design and analyzed the proposed transportation, facility, and inventory carrying cost by using anyLogestix software.

2.5. Conceptual RLND for the SLAB recycler

Before model construction with the anyLogestix PLE package, it is first fundamental to obtain an appropriate conceptual model, by which the reverse logistics network design can be described. The structure of reverse logistics network design is need to be considered by different factors such as the number and the type of participants in the system, disposal center, consumers, retailers, collection centers, recyclers, and activities through material flow and product. In the forward network, suppliers, production/recovery centers, and distribution centers are considered whereas the reverse network includes collection centers, disposal centers, and production/recovery centers (Fattahi & Govindan, 2017).

Both forward products and returned products can be transferred via hybrid processing facilities for the advantages of cost savings and pollution reduction as a result of sharing material handling equipment and infrastructure (Lee & Dong, 2009). The integrated forward and reverse logistics network (IFRLN) therefore considers a hybrid distribution-collection facility whereby both distribution and collection centers are established at the same location (Pishvaee et al., 2010). A predefined amount of demand from each customer zone is assumed to result in returned products and a pre-defined value is determined as an average disposal rate. All returned products from first-market customers must be collected and all demand from second-market customers must be satisfied. The recovery process is performed in inspection centers and recovered products are inserted in the forward network and are considered identical to new products.

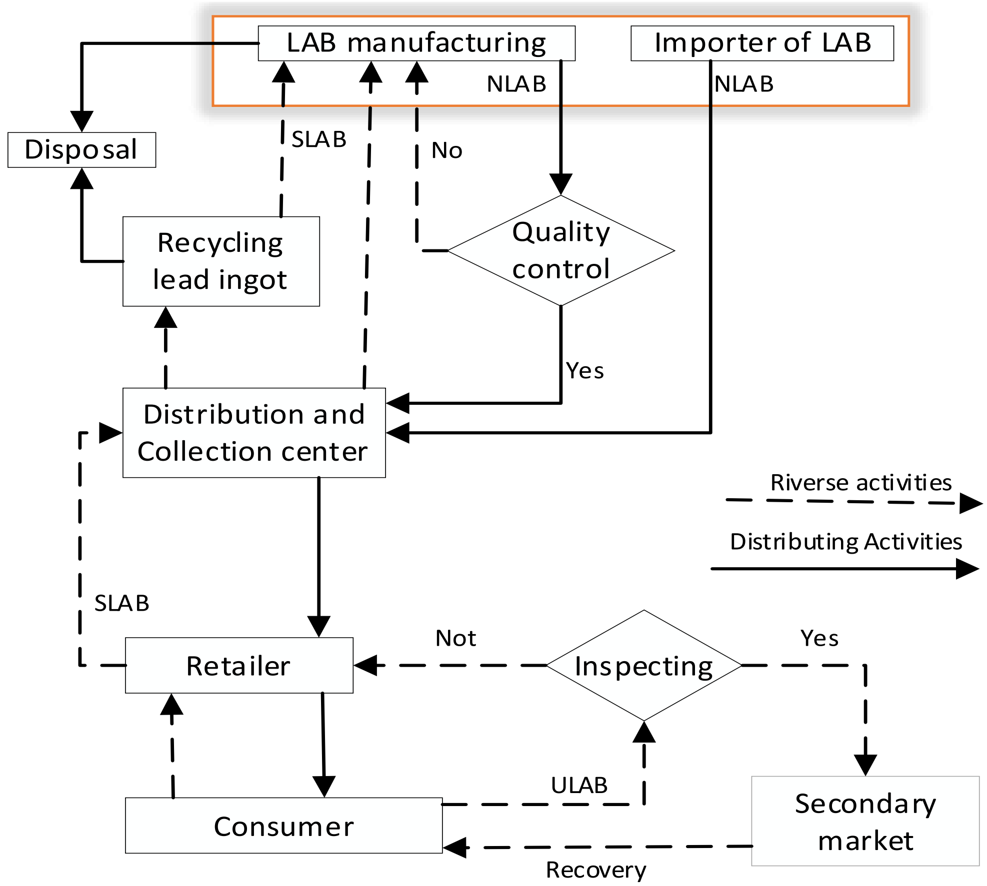


Fig 2-2. Conceptual Integrated RLND Source: Author's based on literature review

Chapter Three:

Methodology

3.1.Introduction

Different types of data-gathering instruments were employed for this study, to combine the strengths and compensate for some of the inadequacies found in any one of the sources of the data. Thus, we discussed and highlighted the overall methodology used in the collection and analysis of data to give solutions for the research questions in consideration of the study. Therefore, we would prefer and used purposive sampling method in carrying out this research. To systematically review the gaps and trends in the research of integrated reverse logistics networks, the research methodology will be illustrated in seven steps: The research design, study area, sample size, the participants of the study, the type of data source, and the research instrument used to collect the data, the methods of data gathering and analysis were presented.

3.2.Study area

This RLND study focuses on partnerships in the system such as consumer, collector and distributor, recycler, and suppliers. The recycler company was selected according to recycling and production capacity and Located in the East Shewa Zone of the Oromia Region town in central Ethiopia which is located 187 Km away from the capital city of Ethiopia. The distributor sample was taken from two federal states (Dire Dawa and Addis Abeba) and four regions and cities (Hosa'ina, Bahirdar, Mek'ele, and Dessie) were selected based on most vehicles obtainable, significant markets for the industries, and geographical area pleasant and center for the distribution of NLAB and collection of SLAB from all district of the region. From six distribution centers twenty customer (consumer) cities are selected based on the most vehicle available amount and population obtainable area as shown in Fig 3-1. Addis Ababa is the capital city of the country and most of the importers, and suppliers are located in the city. Suppose we are seen as 2023 vehicle amount available data from table 3-1. Microgeneration scenarios with suitable battery sizes are found to have lifetimes of 2 – 4 years for high production (Jenkins et al., 2008). Based on the number of obtainable vehicles amounts by dividing the average three years of life service we can get the average available spent lead acid battery amount per year.

Table 3-1: - Number of vehicles in the region. Source: Ministry of Transport

Region	AA	AM	AF	BN	DD	SO	TG	GM	HA	SN	OR
Vehicle No in 2000 E.C	703143	131750	10096	15813	25743	19579	60800	7626	10728	133080	282756
Available Spent/ year in 2023	234,381	43,917	3,365	5,271	8,581	6,526	20,267	2,542	3,576	44,360	94,252

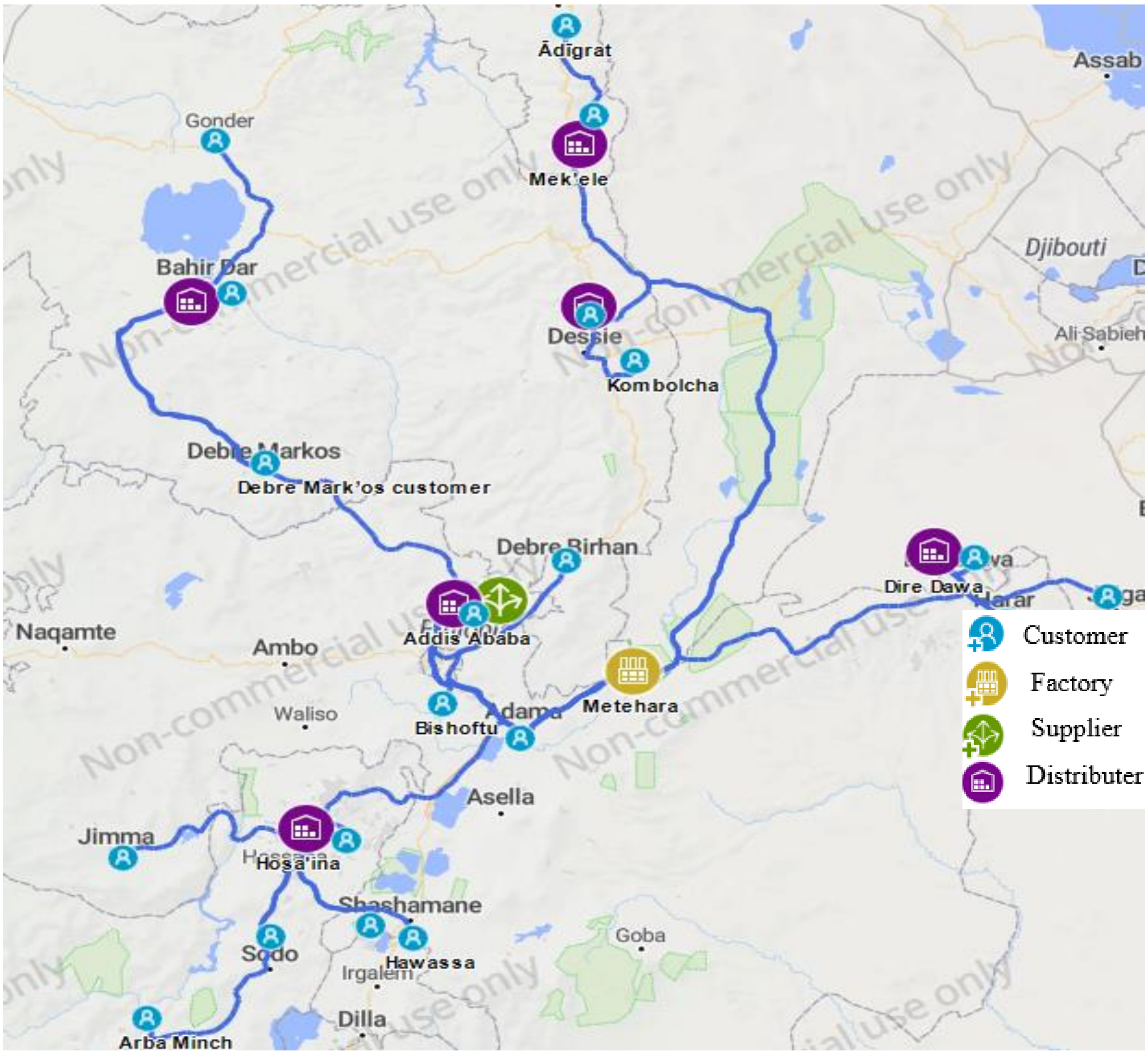


Fig: 3-1: - maps of study area

3.3.Data source

Both primary and secondary data collection sources were used in this study. The secondary data include information that is obtained from published and unpublished sources i.e., from manuals, guidelines, different annual reports, and literature that are relevant to the study, were gathered from various sources. The primary data sources questionary and observation from the selected respondents who were found in the LAB distributor, SLAB collector, consumer (user), and recycler of SLAB. The distributor and collector, consumer (user), and recycler have got experience of at least the past five years. Observations and questionnaires with the selected body and other documents were used as the sources of the data for this study.

Based on these methods, the researcher designed to use non-probability sampling techniques and analyzed RLND & their performance to propose a possible solution pre-dominantly, in the current selected collecting and recycling industry. The respondent is requested to fill out a survey questionnaire from the perspective that best captured the reverse logistics network issues faced by their organization. The questionnaire aims to identify the roles of reverse logistics and the network structure of reverse logistics in sectors, the problems encountered in organizing reverse logistics systems, and the way organizations take in strengthening network design.

3.4.Population and samplings size determination

This research gave significant consideration to ensure the sample represents the population to come up with possible conclusions from the sample outcome. Since this investigation intended to analyze RLND to enhance productivity and profitability, one lead ingot recycling industry, and six distributer organizations. The non-probability sampling method which is called the purposive sampling technique has been taken into application.

The researcher intended to use this approach aiming to collect comprehensive and reliable information from sources having the relevant knowledge and direct related operational experiences directly linked to the subject of the study.

Table 3-2: - Sample size determination

Population-Size	Low Sample Size	Medium Sample Size	High Sample Size
51-90	5	13	20
91-150	8	20	32
151-280	13	32	50
281-500	20	50	80
501-1200	32	80	125
1201-3200	50	125	200
3201-10000	80	200	315
10001-35000	125	315	500
35001-150000	200	500	800

Source: (Dolnicar et al., 1997).

Through this approach, the researcher selected general managers, production managers, technical and operational manager quality department heads, procurement departments, sales & market departments, supervisors, warehouses or store managers, and suppliers as correspondents.

From six distributors there are 104 employees and 32 questionnaires were distributed from one recycler 142 employees and 32 questionnaires were distributed through the selection of the respondents to get relevant information on RLND and their performance measurements in the operational system of the firms.

3.5.Tools used to collect the data

Different types of data-gathering instruments were employed for this study, to combine the strengths and compensate for some of the inadequacies found in any one of the sources of the data. Accordingly, two complementary techniques of primary data collection namely, Surveys and questionnaires, and observation were used to acquire relevant data for the study.

3.5.1. Surveys and questionnaires:

Two sets of questionnaires containing closed-ended types have been administered to collect data from the industries and distributors. These are designed to collect and record information from many people of distributer groups and organizations in a consistent way. A survey typically consists of three different aspects: an approved sampling method designed to ensure the survey is representative of a wider population; a standard questionnaire that ensures information is collected and recorded reliably; and a set of analysis methods that allow results and findings to be generated.

3.5.2. Observation:

The observation was made by using a checklist for each of the targets carried out as a participatory exercise. If this is the case, the program's users and target audience will be involved in observing and discussing findings. Observation is done on the consumer of LAB about the collection system, roles, and activities of LAB, and reverse logistics network design on the SLAB. Fifty-one consumers (buyers) in the areas where they purchase the new LAB were selected to obtain relevant information regarding their performance parameters in the RLND and operating system.

3.6.Research design

Research designs are core issues for studies to be realized. According to different authors, the research design is important to facilitate the smooth- sailing of the various research operations, thereby making research as efficient as possible yielding maximal information with minimal expenditure of effort, time, and money.

Both qualitative and quantitative data were essentially motivated by the need to gain insight into the factors that affect RLND.

3.7.Research framework

Different concepts, tools, and data were applied in designing the following research framework. The study incorporates different stages. At the initial stage, identifying Problems, a review of the literature was made to develop the theoretical background, and instruments of data collection are done simultaneously. In this regard, documents, statistical abstracts, and reports have been reviewed to collect relevant information. Then, the selected recycler industry and distributors of LAB were visited to secure relevant documents and information as a preliminary survey. This enabled to selection of the research area and potential sources of data. Formulation of Problems that are to be resolved.

Objective setting to answer the study questions: Once the objectives of the simulation are well set, simultaneously identify the review literature and identify the gap. Based on the problems, the setting objects, and the review literature is to build a conceptual model of the real-world system using mathematical and logical relationships. Collection of Data to input them into the model; the study tried to collect data, which is up to date from the real system. After the collection of the data, SPSS and anyLogestix analyzer was used and the model product run it fully/till the end & analysis to find out the values/output of the simulation. Verification of the model is done by running the model under the input parameter, and checking that the model output results comparisons with manual calculated results.

Conclusion and recommendation for the purpose this model developed

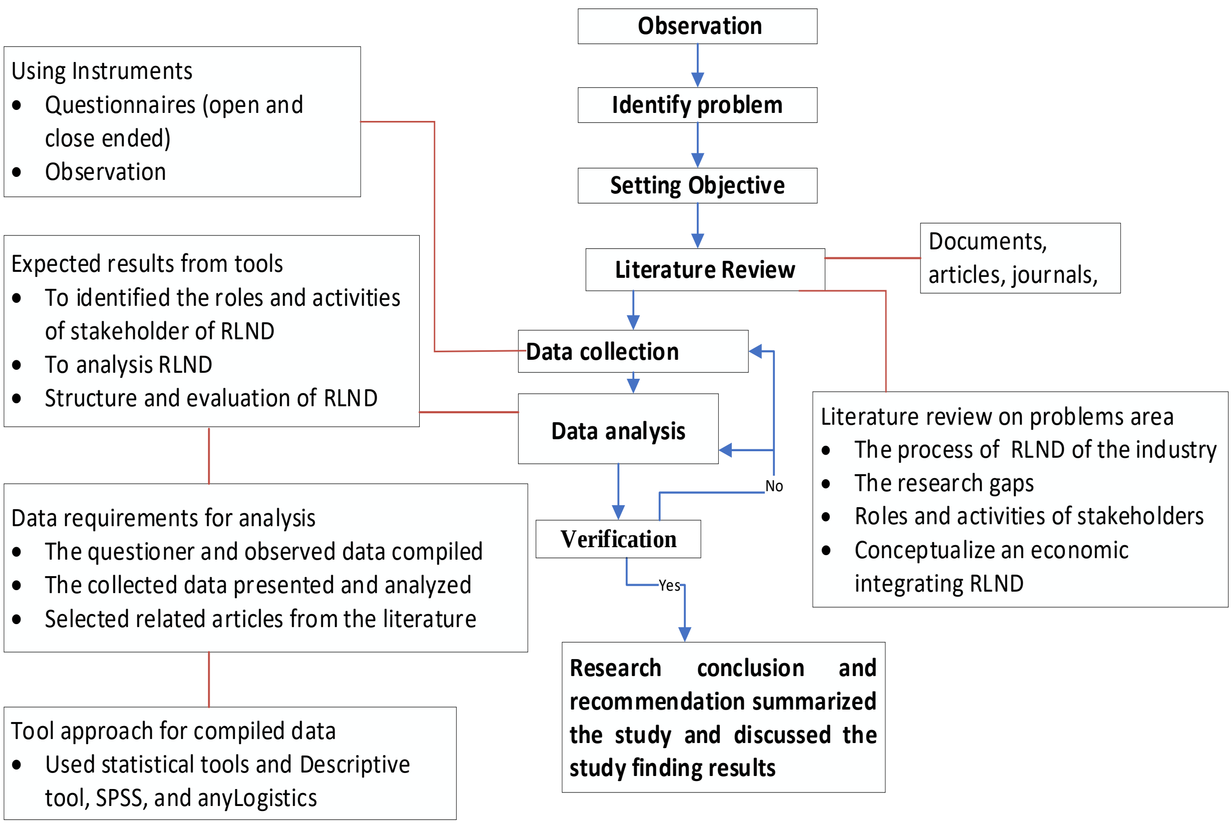


Fig 3-2 Methodological Framework

3.8.Data analysis

After the collection of primary and secondary data, the data analysis was followed. First, SPSS for descriptive statistics have been used. Secondly, anyLogestix software for simulation of analysis economically integrated RLND with the forward logistics. Then tables and charts were used to analyze the output from the analysis. Finally, a suggestion has been given for the main factors of economical RLND formations and evaluation systems.

Then, the research questionnaire has been administered, observations were conducted and documents were collected. Then after, the questionnaires analyzed by both SPSS and multi-echelon solvers (such as anyLogestix software), and the findings were drawn. Based on the findings, a conclusion, and possible solutions were recommended. After using, anyLogestix to select the samples for the study, other data about the selected samples were collected and analyzed using simulation modeling procedures.

Depending on the objective of the study and the nature of the data collected anyLogestix PLE tools for the solution of the system-simulation network problem are used as an approach. The software's framework allows for running experiments. To ensure that the system-simulation network data accurately represent the actual process, enhancing system-simulation network verification of simulation data will be carried out. anyLogestix PLE assists organizations to find one of the best suits their objective and perceptive of the problem. Thus, provides a wide-ranging and reasonable agenda for structuring a decision problem, reflecting and quantifying its elements, concerning those elements to overall goals, and evaluating alternative solutions.

3.9.Ethical Considerations

The study's only goal of conducting educational research was guaranteed by the researchers. The names and addresses of survey respondents were not made public during the data collection and processing process. In the event that subsequent research is released, anonymity will always be maintained, and names won't be included without consent.

Chapter Four:

Result and Discussion

4.1.Introduction

The data collection was conducted with the help of a questionnaire. The questionnaire was formulated based on the factors influencing reverse logistics network design performance. In this section, the percentage of the answers to the questionnaire of the distributor/collector of LAB (SLAB), for the manufacturer of lead ingot and battery factory, and observation from consumers of Lead Acid Battery (LAB) towards the three dimensions in the model are being estimated.

4.2.Response Rate

According to production capacity and type of product, Lead acid battery recycling company was selected around Metehara city of Oromia region and a survey questionnaire was conducted. Most vehicles available regions and most populated cities are selected for the distribution of NLAB and collection of SLAB. In addition to the major markets for the industrial products, Addis Ababa is the capital city of the country and most importers, distributors, and consumers are located in the city. 32 questionnaires were distributed to distributed and 31 were collected response rate 96.875%, from the recycler industry 24 questionnaires were distributed and 24 were collected response rate 100%, among consumers, observations were done on 51 buyers.

4.3.Socio Demographic Characteristics of the Respondents

The socio demographic data of the survey's participating respondent’s businesses are shown in Table 4.1. socio demographic data

Dimension	Rating	N	%
Age of respondent	18-30	**25**	22.6%
	31-40	**67**	19.4%
	41-50	**8**	32.3%
	>50	**6**	25.8%
Academic Qualification	Grade1-12	38	45.2%

	Diploma	14	29.0%
	Degree	8	19.4%
	Master degree	4	6.5%
	No	42	87.1%
Experience	4 – 6	7	6.6
	6 < 8	3	2.83
	8 < 10	5	4.71
	< 10	91	85.85

The majority of the respondent's (86.79%) were below 40 years. This shows that recycler industry, distributer and collectors, and consumer are young. Among academic qualification 88.67% of the respondents were below first degree. This shows there is much to do with less qualification of the workers. 85.85% of respondents had an experience of greater than ten years. This shows that there are good experienced. To sum all up, the sample fits with the recent situation of RLND analysis can be conducted by using this data.

4.4.Response of recycling industry

Frequency Table: - 4-2 questionnaire for the recycling industry

Assurance Dimension	Rating	N	%
Spent/ended lead acid battery material is accepted fr	Scrap Metal Dealers	5	20.8
	Battery maintainer	18	75.0
	Battery distributor and collector	1	4.2
Does your organization have the material flow diagram of forward and backward activities (reverse logistics network design practice at the firm)?	Yes	24	100.0
Do you buy ended/spent lead acid batteries (SLAB) with acid?	Yes	7	29.2
	No	17	70.8
When your factory receives used LAB scrapes, is it covered by bins/containers?	Yes	3	12.5
	No	21	87.5
What types of dismantling methods are used?	Dismantling machine	6	25.0
	Hand Hammer	18	75.0

Is your factory molds of casting lead a combination of conveyor chain mechanisms?	No	24	100.0
Do employees know the characteristics of hazards in LAB?	Yes	7	62.5
	No	17	37.5
Do you use an open furnace type for casting lead ingot?	No	24	100.0
Is the casting area designated for good hygiene and ventilation that exhausts air up?	Yes	24	100.0
Are their research and development of the firm enhancing the development of reverse logistics activities?	No	24	100.0
Are government support and determination for reverse logistics network and firm-level research & development?	No	24	100.0
Does your organization use the intertwined forward distribution of products with a back collection of scrape logistics system by different activities?	No	24	100.0

Source:(Questionnaire 2, 2023)

In the aspect of row material, the spent/ended lead acid battery material is accepted from, majority of the respondents stated are from battery maintainers (75.0%) and the second is from scrap metal dealers (20.8%), and the little is from Battery distributor and collector (4.2%). In the case of the organization having the material flow diagram of forward and backward activities (reverse logistics network design practice at the firm), all of the respondents stated (100%) do not have it. In the case of purchasing ended/spent lead acid battery (SLAB) with acid, all of the respondents stated (100%) without acid. In the case of received used LAB scrapes, is it covered by bins/containers, The majority of respondents stated not (87.5%) while the lowest respondents said it's covered (12.5%). In the case of dismantling SLAB, the majority of the respondents used hand hammers (75.0 %), and little was used (25%) dismantling machines. In the aspect of molds of casting lead, a combination of conveyor chain mechanisms, all of the respondents stated (100%) do not have. When it comes to using open furnaces type, for casting lead ingot, all of the respondents stated (100%) to use closed-type furnaces. In addition, the casting area designated for good hygiene and ventilation that exhausts air, all of the respondents stated (100%). In the case of research and development, the firm enhancing the development of reverse logistics activities, all of the respondents stated (100%) no support. In addition, all the respondents (100%) stated also government does not support and resolve reverse logistics network and firm-level research & development. In the case of different organization activities, intertwined forward distribution of products with a back collection of scrape logistics system, all the respondents (100%) stated as not integrated.

4.5.Response of Distributor/Collector of LAB (SLAB)

The responsiveness dimension involves analysis of the Distributor/Collector of LAB (SLAB)

Frequency table 4.3 response from distributor/Collector of LAB (SLAB)

Assurance Dimension	Rating	N	%
When you sell new LAB are you constantly exchanging (collecting) the spent/ ended lead acid batteries	Yes	3	9.7
	No	28	90.3
Have you received including acid to store spent/used lead acid batteries?	Yes	20	64.5
	No	11	35.5
Do you consider the battery component of sulfuric acid to be Hazardous Waste material?	Yes	29	93.5
	No	2	6.5
Do you consider battery component lead to be Hazardous Waste material?	Yes	10	32.3%
	No	21	67.7%
Do you place collection bins/containers for the collection of used products for service purposes and to store the spent/ended product?	Yes	4	12.9%
	No	27	87.1%
Do you have rules and regulations for the activities of distribution and collection of LAB based on hazardous material?	Yes	3	9.7%
	No	28	90.3%
Is the distribution of new batteries intertwined with the activities of a collection of the spent/ended battery?	No	31	100.0%
	Yes	4	12.9%

Assurance Dimension	Rating	N	%
Do you know the distribution and collection regulations of FDRE Proclamation No.1090/2018 Hazardous Waste Management and Disposal Control?	No	27	87.1%
Do you have certification from the Environmental Protection Agency (EPA) for the distribution of new LAB or collection of Spent/end?	Yes	4	12.9%
	No	27	87.1%

In the case of the distributor selling a new LAB the majority of the respondents (90.3%) don’t collect the spent product and the smallest number of respondents are (9.7%) collected. In the case of the respondents stated that had received acid to store spent/used lead acid batteries (64.5%) and the lowest number of respondents was relatively little (35.5%). The majority of the respondents stated that consider the battery component of sulfuric acid to be hazardous waste material (93.5%) when they are not considered as hazardous material relatively little (6.5%). In the case of the study considering batteries, component lead is hazardous waste material indicated by the smallest elegances (32.3%) and stated the majority are (67.7%%) not considered hazardous material. In the case of placing collection bins/containers for the collection of used products for service purposes and to store the spent/ended product the majority of the respondents don’t place them (87.1%) and the lowest are placed (12.9%). In the case of rules and regulations for the activities of distribution and collection of LAB based on hazardous material, the majority of respondents stated (90.3%%) are not have while the lowest have (9.7%). In the case of distribution and collection regulations of FDRE Proclamation No.1090/2018, Hazardous Waste Management and Disposal Control majority of respondents stated not known (87.1%) while little is known (12.9%). In the aspect of certification from the Environmental Protection Agency (EPA) for the distribution of new LAB or collection of Spent/end majority of respondents' responses do not have certification (87.1%).

4.6. Observation from consumers (user) of LAB

The checklist dimension involves analysis of the observations of customers

Frequency Table: - 4-4 observations of customers

Assurance Dimension	Rating	N	%
Consumers know the reverse logistics network activity on the spent lead acid battery.	No	51	100.0
Consumer-aware aware hazardous elements of lead-acid batteries	Yes	15	29.4
	No	36	70.6
Consumer disassembly spent/dead lead acid batteries	Yes	7	13.7
	No	44	86.3
If the spent/used LAB is not properly collected by the collector (a retailer or a distributor) do they know the impact on the environment? Societal? Economical?	Yes	11	21.6
	No	40	78.4
Are there any regulations or rules regarding returning(exchanging) their dead/ spent battery when buying a new one	No	51	100.0
Consumers (their organization) when buying a new battery, to whom the spent/ended lead acid battery back.	Scrape dealer	7	13.7
	Battery Distributor/retailer	2	3.9
	Battery maintainer	11	21.6
	Automotive workshop	5	9.8
	Not back	26	51.0
Consumers (their organization) buy a new battery, why not back the spent/ended lead acid battery	Lack of incentive to return	10	19.6
	Lack of suitable sites for back	15	29.4
	There are no services available	3	5.9

	Unwilling of the distributor to collect	23	45.1
Consumers (their organization) know your roles and activities on the spent lead acid battery	No	51	100.0

Source:(Observation)

In the case of reverse logistics network activity on the spent lead acid battery, all of the consumers do not know. In addition, consumers are aware (29.4) of the hazardous elements of lead-acid batteries, and the majority of consumers (70.6%) do not have them. In the case of spent/used lead acid batteries, if not properly collected by the collector (a retailer or a distributor) they know that it will have an impact on the environment. Societal? Economical, the majority of not known (78.4%) and the lowest know (21.6%). In the case of any regulations or rules regarding returning(exchanging) their dead/ spent battery when buying a new one, all of the consumers do not have (100%). Around their purchasing activities area consumers (their organization) when buying a new battery, to whom the spent/ended lead acid battery back, majority of the consumer not back (51%), second for battery maintainer (21.6%), third for scrape dealer (13.7%), forth for the automotive workshop (9.8%) and lowest for battery distributor/retailer (3.9%). In the case of consumers (their organization) when buying a new battery, to whom the spent/ended lead acid battery back., majority the reason unwilling of the distributor to collect (45.1%), second for lack of suitable sites for the back (29.4%), third for lack of incentive to return (19.6%), forth for services unavailability (5.9%). When comes to the customer, knowing their roles and activities on the spent lead acid battery, all they are not know.

4.7.Existing practice of lead acid battery reverse logistics network in Ethiopia

SLAB includes economic design problems in articles on reverse logistics network design for hazardous waste, so these articles are system optimization problems. The study focused on this type of problem in simulations of the economical reverse logistics network optimization problem and profit maximization.

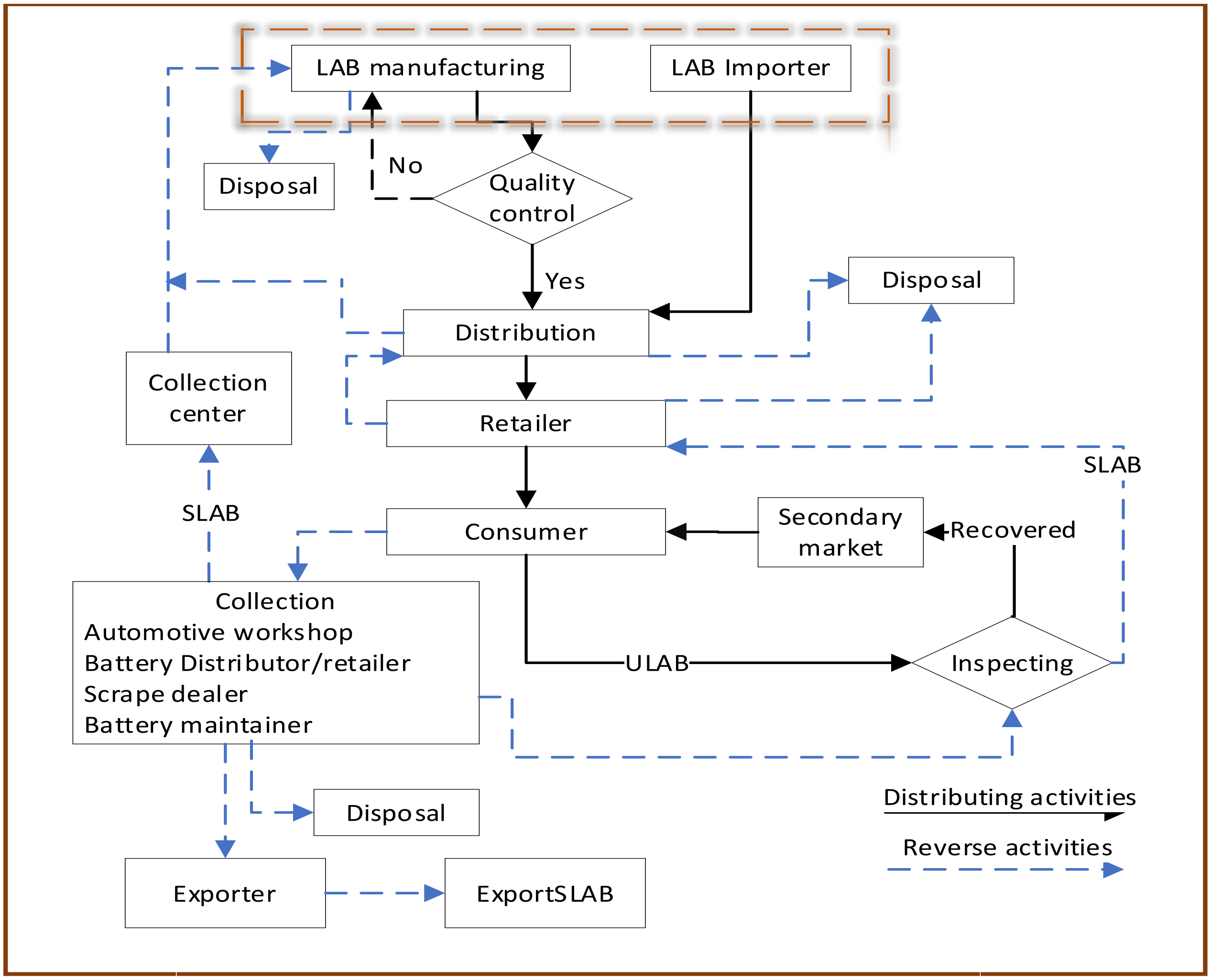


Fig 4-1: - Existed forward and reverse LND

At the current stage, the country does not have the lowest cost solution of a strategic design for using a well-defined reverse logistics network design approach to get spent product in the company that meets the customer proposition. The spent product is collected from consumers through the collector of the Automotive workshop, Battery Distributor/retailer, Scrape dealer, and Battery maintainer to the collection center and retailer they are transported to the recycling plant where recycling is done and finally converted to lead ingot, new battery production, and other lead products.

According to report of Ethiopian manufacturing technology and engineering industry research and development center, recycler industries of Ethiopia operate as a manufacturer and exporter of lead metal and its products. The process is performed at relatively low temperatures and produces both lead metal and dross by smelting and recycling processes; the dross is recycled by smelters. Aside from lead processing, industries are engaged in the trading of lead scrap, lead battery scrap, and lead products. Lead–acid (LA) batteries percentage by weight contain metallic lead 34 %, lead peroxide 31%, lead sulfate 1%, and sulfuric acid 34% (Drive, 2017). The SLAB is processed into recycled plastic: polypropylene consumption as battery boxes and lead compounds into metal by smelting and refining for new applications, like batteries (Jolly & Rhin, 1994). These factories then further convert lead metal to LAB for power storage use and distribute it to various distribution centers located in the region, from where the customer fulfillment is met by the various retailers who take the finished goods from the distribution centers. The refining plan uses a conventional process to recover nonferrous and precious metals from spent lead acid batteries (pyro-metallurgical process) for lead refining, producing 9,650,000 kg/year capacity of lead with a purity level up to 99.9% by process of removing slag and hot metal from furnace hearth crude lead.

As an observation from questionary in the industries from company owners, managers, and experts through this project the following problem areas are identified for improvement in the reverse logistics network design of the plant. The collection of SLAB is irregular and the company is unable to forecast its products and does not have a well-structured model practice of reverse logistics network design as well as performance evaluation criteria of the company. Underutilization of existing workstations due to poor practice of reverse logistics network design problem.

Based on the average 3 years battery life service from years of 2000 GC obtainable vehicle amount 1,147,244 data in a country, 382,415 pcs of SLABs are found in 2023. However, industries can collect 27,150 spent products from 2023 on average, and different collectors: scrape dealers, battery maintainers, automotive garages, and distributors/retailers are collected and exported through exporters 125,676 SLAB within 2023. Which is less than 40 percent potential from obtainable spent production. Due to improper reverse logistics network design problems and some of the unstated roles and activities of stakeholders' industries are unable to increase their collection of SLAB and productivity.

To solve the above-mentioned problems and enhancement of performance an integrated model of reverse logistics network design with existing distribution networks based on the cooperation of stakeholders, stated roles and activities within a simulation environment, which is capable enough to predict the future performance of the company.

4.8. Reverse logistics network design using anyLogestix software

4.8.1. Assumptions and key input data

A few assumptions are made based on the anyLogestix software parameters to implement the case study.

- All the roads that connect the different places in the case study, whichever is the correct one, the shortest path between the two points is chosen.
- The price of raw material (per kg) remains constant irrespective of the market demand factors.
- All distributor of NLAB is considered collectors of the SLAB
- From Table 3-1 available SLAB amounts are collected and NLAB is distributed based on the collection amount of spent product. The price of spent lead acid batteries back to the industry through the existing distribution network and considered free of cost.
- Based on the industry capacity and available spent products the selected region and city are considering the palpable amount and capability for the collection of spent products from less than 40 percent to 100 percent and distribution of new products.
- The industries of universal metals and Minerals plc addition to lead ingot production can have a plan to start battery. Therefore, considering ingot factories and battery factories is palpable.
- Customer demand of product LAB unit pcs with in order interval days are 30 and the collection process is done simultaneously with the distribution activities as shown in table 4-7.
- The simulation is considered for one year.

4.8.2. Inputs considered and collected

- The shelf life of lead-acid batteries is limited therefore inventory policies at each site of the supply chain take into account order on demand. Each manufacturing and smelting unit had defended for initial inventory. Average caring costs are considered 1 birr/pcs for the proposed network design and 2 cost/pcs for the existing one.
- Transportation path vehicle type truck and the peak capacity of the truck is considered 20000 kg with an average speed of 40 km/hr. Less than load (LTL) is considered for the transportation of goods. Distance unit is km and 0.05 birr/(kg.km) for the proposed design and 0.1 birr/(kg.km) for existing transport because distribution and collection activities are done separately therefore costs are multiple compared to the proposed value.
- Facility costs are considered 0.4/pcs for the proposed network design and multiple for the existing value.
- Production time is 0.0443 per unit of product LAB and 50 birr of production cost.

Table 4-5: - selling price and cost prices of battery elements and products.

Name	Selling price (birr/kg)	Cost price (birr/kg)
sulfuric acid		3.92
LAB	234.43/kg	

Source: Company

Parts of LAB such as metallic lead, lead dioxide, and polypropylene plastic of product cover recycled from SLAB.

4.8.3. Reverse logistics network design

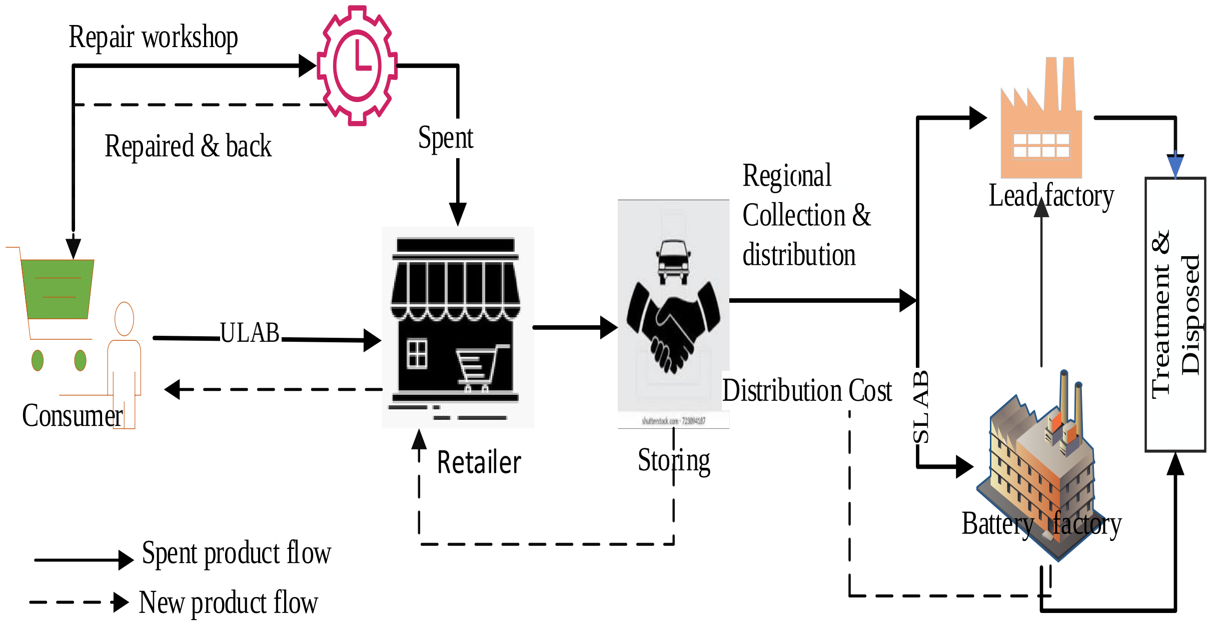


Figure 4.2: RLND integrated with existed forward logistics network

To demonstrate the validity proposed design and develop integrated of reverse logistics network design with the existing forward distribution. The starting point of the simulation is in the" Creation and Assigning of Collector" on the existing of distribution the new product model, where six supplier batteries are selected and then integrated collectors with the existing distributor of products for simultaneous activities. The first process in the model is to determine the area of the collection center in which battery warehouses are selected by the geographical area pleasant for collection purposes, most vehicle obtainable region, and populated city. The collection of SLAB is assigned to the battery retailer.

The retailers are then Transferred through the existing distribution network back to the regional distribution and collection center of the warehouse. From the center or bulk consumer, the organization is brought into a disassembly plant where they disassemble and separate different components of batteries and finally lead scrap and plastic scrap recycling to LAB by adding future battery elements.

4.8.4. Simulation network design and analysis

Experiments are carried out in the existing forward logistics network to demonstrate the validity of the proposed optimization model and realize an integrated reverse logistics network design. The designed reverse logistics model is implemented by integrating the existing using the proposed multi-echelon SIM and validated by using available SLAB data collected in six regional collection centers, one recycling factory, one supplier, and twenty customers city, and simulation used in these experiments.

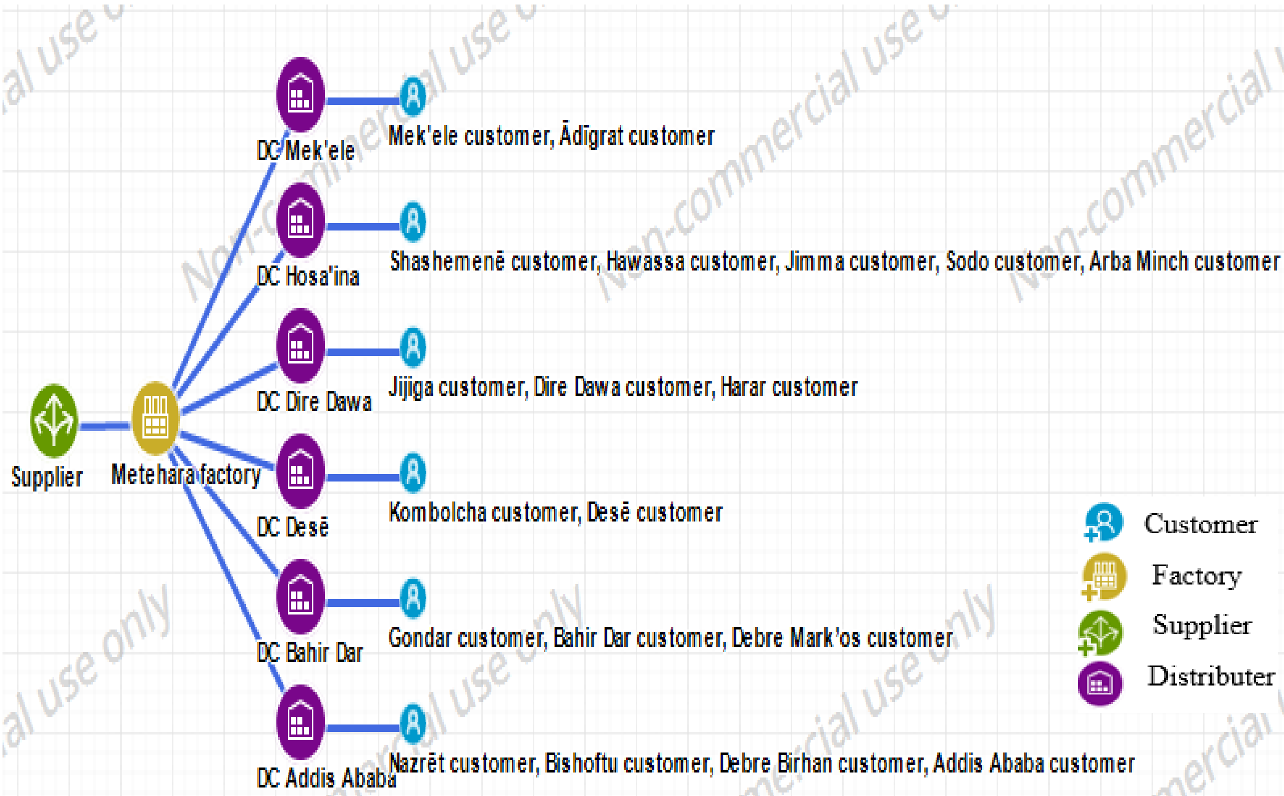


Fig 4-2. simulation network design

Spent and new lead acid batteries are sets of the same size and shape. It’s easy for simultaneous distribution and collection that arises when the distribution of goods from a depot to a set of customers and the collection of waste from the customers to the depot can be performed simultaneously.

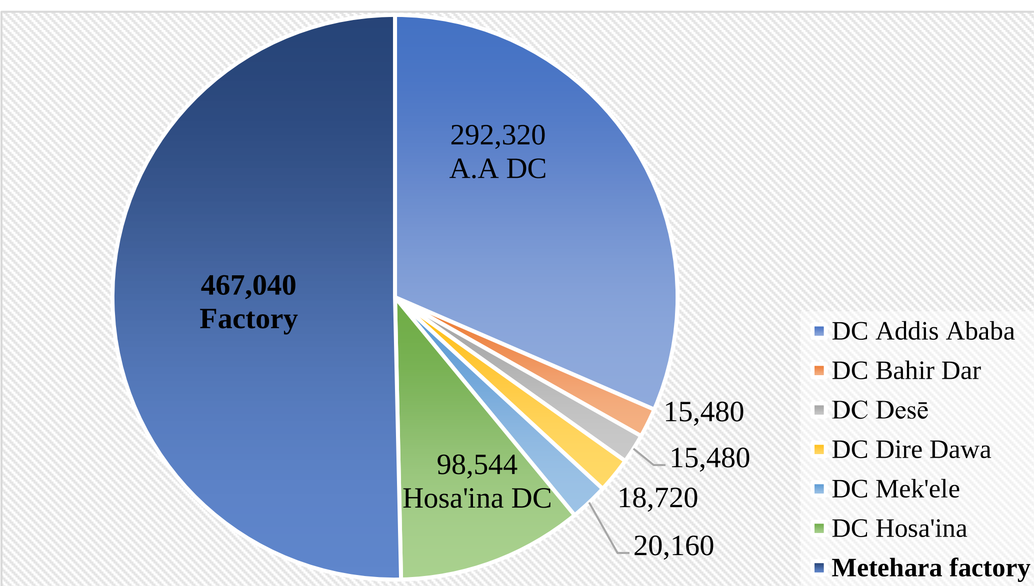
Table 4.7 shows the results of various parameters considered in this study consisting of production cost, facility expense, inventory cost, and transportation cost at each node simulated by the anyLogestix software.

The setup is done and the inventory policies at each node along with the selling prices of each manufactured LAB product are given as input into the anyLogestix for simulation. Financial performance indicates the benefit in sales and revenue strengthened by various components of the RLND with the integration of the existing supply chain network design. Product and sourcing standards provide insight into how products move along the supply chain and product movement.

Production costs, facility expenses, and inventory costs are related to product value. Remanufacturing costs are related to product value and the complexity of remanufacturing operations. Transportation costs are calculated based on the distance and product mass (kg). Since the products were returned by customers themselves or collected by the distributor, the transportation costs between customers and regional collection centers (distributors) are not considered. Some of the used products that can be reused are sent to repair centers and used by consumers. Transportation costs between suppliers and remanufacturing centers are not considered because the suppliers are in charge of the costs.

The cost price of the SLAB is back to the industry through the existing distribution network and considering delivery to the recycling industry at zero cost.

Table 4-6: -factory recycling of SLAB, and distribution of NLAB and collection of SLAB per year.

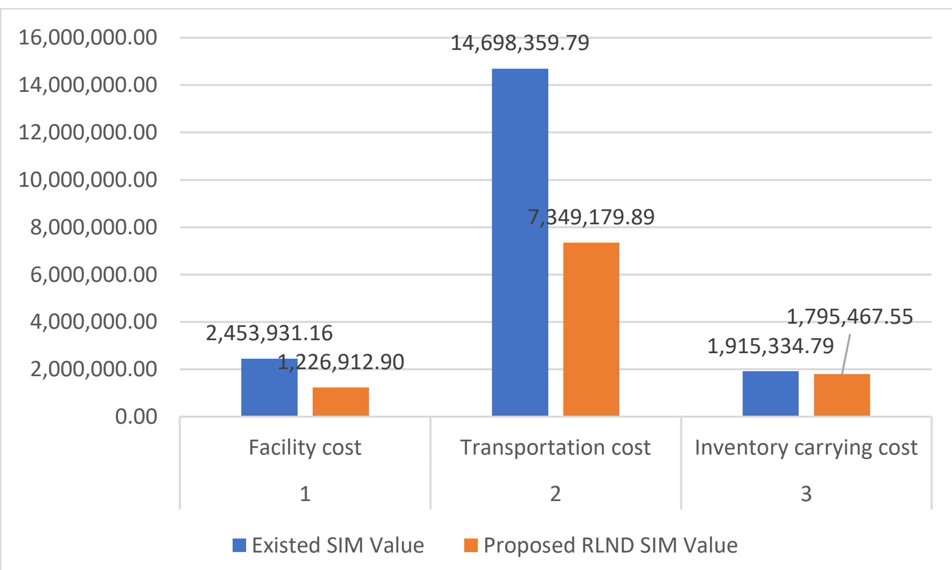


To solve the problem first, determine yearly a country's demand for LAB based on obtainable vehicle amount as shown in chapter 3 table 3-1 and can predict the spent product amount from the recycling capacity of the industry. After determining the demand from each customer zone is assumed to be returned and the average spent product amount is also predetermined. Besides determining the customer demand and the spent product obtainable region (sourcing of row material), facilities levels, and industry recycling capacity to achieve integrated forward and reverse logistics network design to obtain minimum costs design and maximum profit. In addition, the important problems addressed in this study are as follows: Determining the production and recycling amount, distribution and collection capacity, as well as the product flow between the facilities.

4.9.Simulating results and analysis

In this paper, only the differences in objective value between the proposed RLND and anyLogestix are provided to show the efficiency and effectiveness of the proposed integrated design.

Table 4-7: - the result of the profit and loss statement



	Statistics Name	Proposed RLND SIM Value	Existed SIM Value
4	Production cost	21,271,750	21,271,750
7	Profit	76,503,976.32	67,344,439.94

According to the objective function and conditions of the multi-echelon reverse logistics network, the optimal number of collection centers and other facilities for the SLAB can be solved through the above numerical data.

Since the purpose of this research focuses on the reverse logistics network design is useful for the collection and recycling of SLAB, the computation comparison is not a major concern in this paper. The integrated SIM is designed to help solution decisions in reverse logistics. In this paper, only the differences in objective value proposed integrated SIM are provided to show the efficiency and effectiveness of the proposed integrated SIM. The results show that the proposed integrated SIM outperforms anyLogestix in solving the problem.

The optimal locations of reverse processes are solved from the designed model integrated with the current distribution network implementation. The proper facilities for each echelon of the reverse logistics network solved from the designed model. Findings of one-year simulation experiments highlight substantial improvements in operational performances for the finances compared to the existing network, particularly on: transportation cost, inventory carrying cost, and facility cost.

4.9.1. Transportation Cost

The integrated network on existing configuration brings potential cost savings to back the spent products. Distance unit is km and the selected truck is loading up to 20,000 kg and 0.05 birr/kg/km for the proposed design and 0.1 birr/kg/km for existing transport because distribution and collection activities are done separately therefore costs are multiple compared to the proposed value. The simulation selects a simple path and analysis of the cost value as shown input data below from the factory to six distributions and up to the destination of the customer.

Table 4-11. transportation Cost

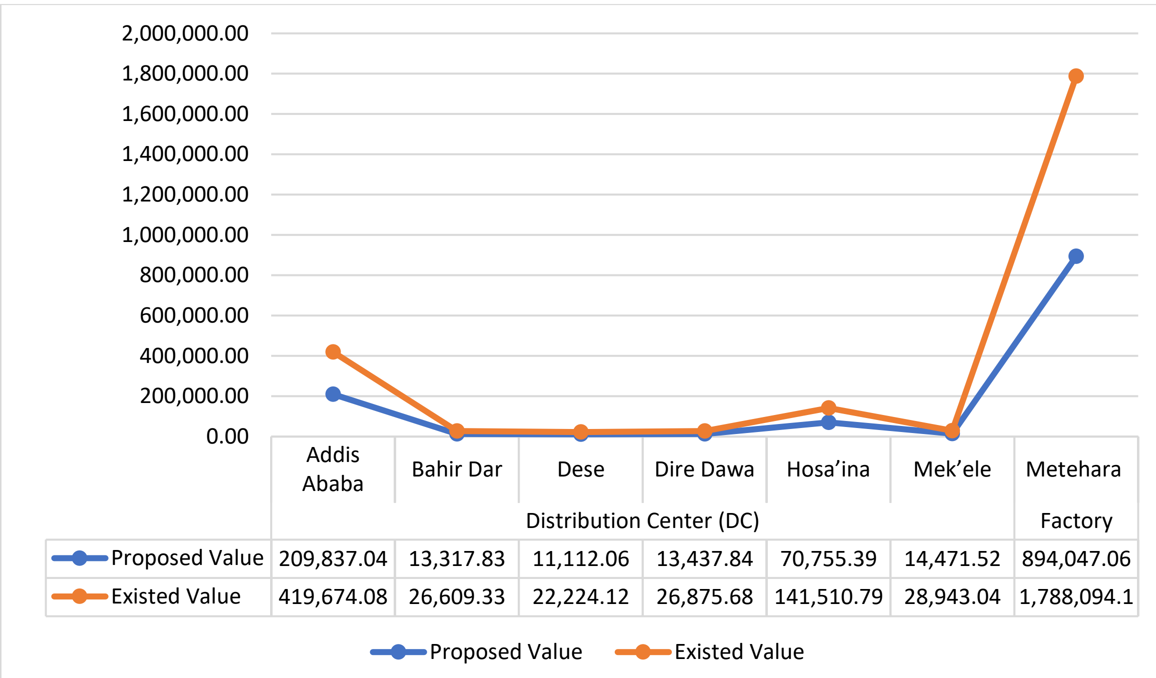
No	Type and Object	Destination	Existed value	Proposed Value
1	Metehara Factory to	Addis Ababa DC	5,114,790.60	2,557,395.30
		Hosa’ina DC	3,114,759.92	1,557,379.96
		Mekele DC	1,374,879.15	687,439.57
		Bahirdar DC	1,298,364.05	649,182.02
		Dese DC	808,324.09	404,162.14

		Dire Dawa DC	552,358.93	276,179.46
2	Hosa'ina DC to	Jima Customer	543,044.61	271,522.31
		Ariba Minch customer	280,506.84	140,253.42
		Shashemene Customer	258,439.35	129,219.67
		Hawassa customer	171,523.51	85,761.75
		Sodo Customer	126,679.66	63,339.83
3	Addis Ababa DC to	Debre Markos customer	231,011.75	115,505.87
		Nazret customer	218,687.73	109,343.86
		Bishoftu customer	121,045.54	60,522,77
		Debre birhan	100,595.13	50,297.56
4	Bahirdar DC to	Gondar Customer	130,162.38	65,081.19
5	Mekele DC	Adigrat customer	116,237.46	58,118.73
6	Dire Dawa DC to	Harar	18,505.62	9,252.81
		Jigjiga	100,566.12	50,283.06
7	Dese DC to	Kombolcha customer	17,877.27	8,938.63

4.9.2. Facility cost

All costs associated with the day-to-day operations, maintenance, and administration of the facilities (Hui & Tsang, 2004). Regarding financial measures, the integrated network surpasses the existing one regarding all measures. The two lines of the different facility are to indicate the initial arrival station where the row material is received and then transported to the battery factory using integrated on the existing facility and the other using separately from the existing network consumes its own facility cost. Therefore, facility expense in all sites is 0.4 birr per day for one pc average for the proposed network design and multiple for the existing value.

Table 4-9: - facility cost

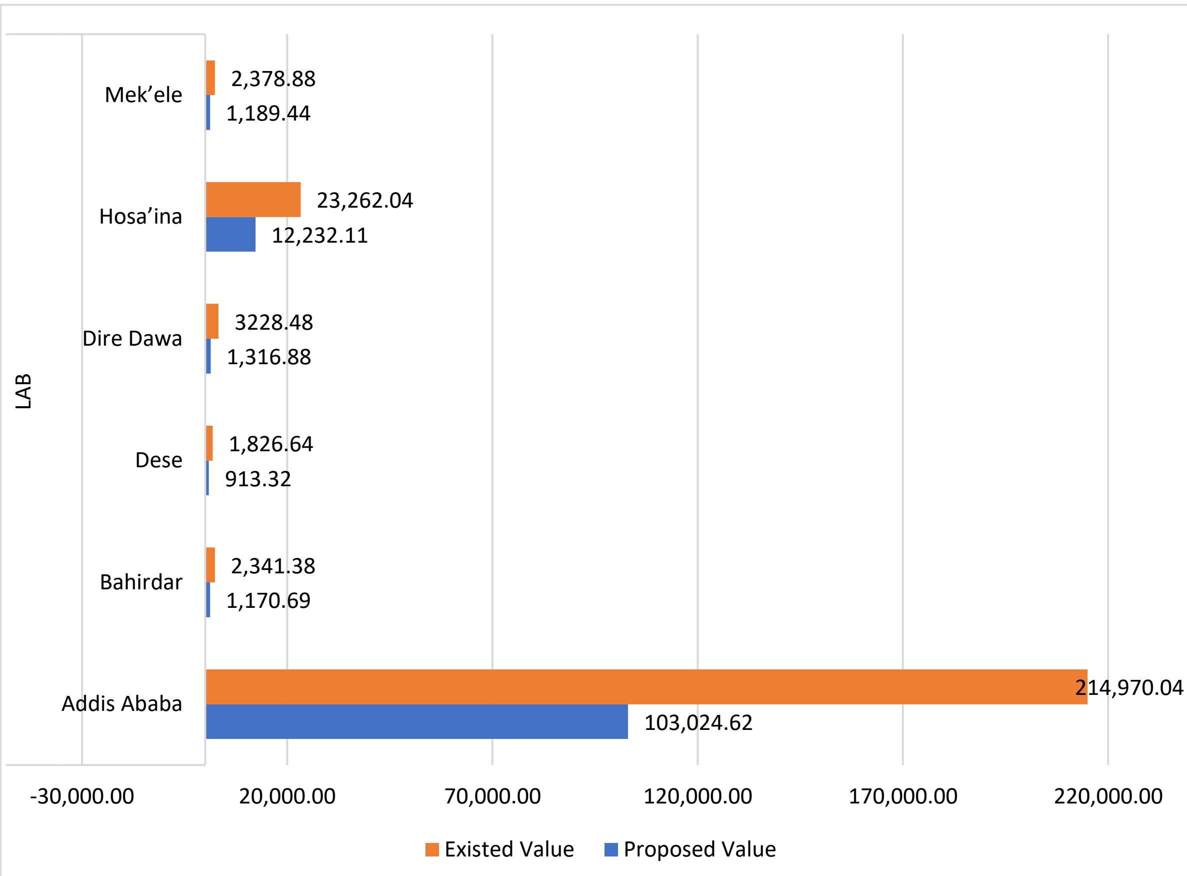


	Addis Ababa	Bahir Dar	Dese	Dire Dawa	Hosa'ina	Mek'ele	Metehara
	Distribution Center (DC)						Factory
Proposed Value	209,837.04	13,317.83	11,112.06	13,437.84	70,755.39	14,471.52	894,047.06
Existed Value	419,674.08	26,609.33	22,224.12	26,875.68	141,510.79	28,943.04	1,788,094.1

4.9.3. Inventory carrying cost

Based on the expected stock lifetime of the product for inventory carrying cost order demand policy is followed and for the simulation initial stock amounts are taken from yearly consumption of the product to monthly distribution and collection of spent product amount. Inventory caring costs are considered 1 birr/pcs for the proposed network design and 2 cost/pcs for the existing one because the forward flow of product and backward flow of spent collection are not integrated.

Table 4-10: - inventory carrying cost for the proposed and existing distribution collection process.



In the experiments, recycled products are based on the maximum distribution product. The extra products are kept in inventories for future use.

4.10. Verification of the Study

The final way for the verification of the model is done by running the model under the input parameter, and checking that the model output results comparisons with manual calculated results.

Verification concerns with the operational model (whether it is performing properly). It is done to ensure that:

- the model is programmed correctly
- the model does not contain errors, oversights, or bugs.

The associated parameters are set constant for calculating the transportation costs by using deterministic data. This includes truck load item amount, transporter cost per (km*kg), and its travel distance. The costs per part are calculated by using,

$$Transportation\ \frac{cost}{part} = \frac{Transportation\ distance * Transportation\ \frac{cost}{(\mathrm{km.kg})} * mass(kg)}{No.of\ transported\ part\ per\ trip}$$

- Transport cost / km = [0.1 cost/ (km * kg)] * mass(kg)
- 1 No of transport parts per trip = 1 parts

No	Type and Object	Destination	Distance (km)	Demand	Existed simulation	Manual	Difference
1	Metehara Factory to	Addis Ababa DC	183.8	292,320	5,114,790.6	5,372,841.6	4.8%
		Hosa'ina DC	320	98,544	3,114,759.92	3,153,408	1.22 %
		Mekele DC	746	20,160	1,565,184.74	1,503,936	0.09%
		Bahirdar DC	677	15,480	1,045,770.58	1,047,996	0.2%
		Desie DC	489	15,480	789,304.8	756,972	4.09%
		Dire Dawa DC	311	18,720	599,704.22	582,192	2.92%
2	Hosa'ina DC to	Jima Customer	321	23,220	711,192.38	745,362	4.58%
		Ariba Minch customer	217	13,032	280,506.84	282,794.4	0.8%
		Shashemene Customer	121	23,220	269,222.18	280,962	4.17%

		Sodo Customer	96.1	13,032	126,679.66	125,237.52	1.13%
3	Addis Ababa DC to	Debre Markos customer	298	7,740	231,011.75	230,652	0.15%
		Nazret customer	94.8	23,220	218,687.73	220,125.6	0.65%
		Bishoftu customer	64.8	23,220	149,538.09	150,465.6	0.61%
		Debre birhan	130	7,740	100,595.13	100,620	2.47%
4	Bahirdar DC to	Gondar Customer	169	7,740	130,162.38	130,806	0.49%
5	Mekele DC	Adigrat customer	116	10,080	116,237.46	116,928	0.59%
6	Dire Dawa DC to	Harar	67.8	3,600	23698.37	24,408	2.9%
		Jigjiga	169.7	6,480	110,504.15	109,965.6	0.48%
7	Dese DC to	Kombolcha customer	21.2	7,740	16,586.71	16,408.8	1.07%

In recycling process, model verification took place as a continuing process. In this case, the percentage error is at an acceptable level of less than 5%.

Chapter Five:

Conclusions & Recommendation

The proposed roles and activities of stakeholders on a framework can enable the reverse logistics network to make informed decisions about transportation, and storage requirements, but also to perform analysis and to be capable of the performance of network configurations. This study can support decision-makers in diverse decisions on network design. By performing decision makers can identify and filter the potential locations for setting up distribution and collection facilities, and make strategic decisions about the number and locations for the distribution and collection network.

This paper has demonstrated the applicability of the proposed decision support framework for reverse logistics network design using the real-life case of the recycler industry on the distribution of LAB and collection of spent products. The proposed model can enable decision-makers to define the optimum network configuration by starting from a list of potential candidates (location using an existing list of consumers as per the current case).

The identified set of existing facilities will guarantee enhanced cost-effectiveness of distribution operations with potential cost savings in transportation and warehousing without additional cost for the activities to back the spent products when measured via simulation.

The network configuration in terms of locations for the existing distribution facilities can be determined with the use of a NO approach. The locations of the 6 DCs should be in A.A., Bahirdar, Hosana, Mekele, Dire Dawa, and ‘Dese’. All DC will in its place be dedicated to the distribution of LAB and collections of the spent product (as per existing). Transportation Policies of the network acquire a product and distance based on the transportation fleet to cover average demand.

For future research, the simulation model can be expanded to include the collection and distribution center involved in the integrated reverse logistics network design problem. In addition, it addresses the multi-objective treatments which explicitly analyze facility cost and also include labor cost and taxation.

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