# Addis Ababa University

## Collage of Business and Economics school of commerce

## Department of logistics and supply chain Management

**Integrated Sustainable Transportation Network Design using Transportation, Transshipment and Vehicle Routing optimization: A Case study of Moha Soft Drink industry S.C**


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ADDIS ABABA, ETHIOPIA

May, 2026

**THESIS APPROVAL**

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# DECLARATION

I, hereby declare that this thesis entitled “Integrated Sustainable Transportation Network Design using Transportation, Transshipment and Vehicle routing optimization: A Case study of Moha soft drink industry S.C”, is my original work and has not be presented in a degree in any university, and also all source of material that used in the thesis have been dully acknowledged .

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## ACKNOWLEDGEMNT

Foremost, I would like to express my gratitude to my advisor Dr.Kirubel ,for the continuous support ,valuable guidance and criticism .His guidance help me a lot throughout the entire thesis starting from choosing the right title .I could not imagined having better advisor for my master's thesis .

Beside my advisor, I would like to thank all employees of Moha soft drink Tekelehaymanot and Dessie plant ,especially the plant manager ,fleet coordinator, plant sales coordinator ,area sales manager ,for their willingness for giving useful information .i would like to give my gratitude to Mr. Seyfe from teklehaymanot plant and Mr.Efrem endale from dessie moha plant .

Lastly, I should acknowledge my treasured family They were supporting me and give me love throughout the post graduating program : Eskedar,Biruktawit,Abraham

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## List of Acronyms

**VRP:** Vehicle routing problem: focuses on finding the optimum route for a fleet of vehicle to deliver to various locations.

**THP:** Teklehaymanot plant: one of industrial manufacturing and bottling factory in Addis Ababa ,operated by Moha of drink industry S.C.

**GHGS:** Greenhouse gases: gases that found in the earth atmosphere that trap heat.

# Abstract

*The purpose of this paper is to integrate Sustainable Transportation Network Design through the application of transportation, transshipment, and vehicle routing optimization models. A mixed-method research approach combining qualitative and quantitative methods was adopted with a in the distribution system of Moha Soft Drink S.C. The database consists of 10 interviews and 49 documents, the current distribution system is largely experience based and lacks integrated optimization mechanisms. The application of optimization models highly reduced transportation cost, improved vehicle utilization, minimized unnecessary travel distance, and enhanced route efficiency. Furthermore, the optimized distribution network improved sustainability through reduced fuel consumption and lower transportation related environmental impact. The optimization network reduces total transportation cost from 23,712,296 to 4,292,000 then 623,868.70 then finally to 466,093.44 and decreased total carbon emission by 285.21kg per kg. The findings contribute to theory development at the intersection of transportation, transshipment, and vehicle routing models provides an effective framework for designing sustainable logistics systems within the beverage industry. By diffusing knowledge regarding available remedies, the study contributes to improving sustainability effectiveness, thereby fostering both practical and theoretical insights into supply chain optimization and sustainable transportation management. This research highlights the criticality of Sustainable Transportation Network Design .The sustainable transportation network effect on Using Transportation, Transshipment, and Vehicle Routing Models reduced fuel consumption and lower transportation related environmental impact.*



***Keyword*** *Sustainable transportation, Transportation model, Transshipment model, Vehicle routing problem, Logistics optimization, Beverage distribution.*

# Chapter one
# 1. Introduction

This chapter contained background, statement of the problem, objective, hypothesis, and significance of the study, scope of the study, limitation of the study and organization of the study.

## 1.1 Back Ground of the Study

Nowadays supply chain requires optional methods to remain competitive in the competitive market that is not only having low cost , but also companies must have good quality product ,manufacture them quickly and meet delivery time as well as flexible and innovative (Coello, G.E.B & Toba r ,J.A.P, 2018).on the other hand ,it is known that supply chain consist of joint activities between suppliers and connected customers that allow to respond to the demand ;it is sought that execution of the activities to be coordinated with the flow of the whole chain ,and in this way ,respond in a timely manner to the customer.

Therefore, supply chain management allows to have strategic view on the management of inputs and flows with in the internal and external process of the company, with the aim of making each link in the chain more efficient (Aldana-Bernal, J.C.,& Bernal –Torres,C.A., 2018).

With this context, distribution in logistics involves preparing product in the distribution center and timely deliver the product according to the customer want (Hua, 2014) .

The transportation model deals with linear programming which has the objective of transporting homogeneous product from different factory or depot to the customer at low total cost (Panneerselvam, 2012) .

Determining the distribution route taking in to account transportation equipment used by pickup and labor cost must be considered because it affects the company’s operational cost. Using optimal distribution helps the company not only to reduce cost but also increase customer satisfaction and also factory's should occupancy prospective distributor to subordinate the market (W sabani, 2019).

Therefore, integrating transportation and transshipment model provides a framework for identifying the most cost-efficient routing plan (Suarez et al., 2021).

This study seeks to evaluate the existing distribution system and company’s transportation system of Moha soft drink .it also analyze alternative routing option that may reduce pollution through transshipment, transpiration model and vehicle routing.

## 1.2Statement of the Problem

Transportation has vital role in the supply chain networks, directly influence cost efficacy, on time delivery and environmental sustainable(Javanpour et al.,2025).According to the 2019 report of the world energy outlook series, the future estimation of energy systems indicates that a serious loss will happen by 2040 (World Energy Outlook , 2019) . This future decline in fossil energy availability and the pollution generated by unnatural resources lead to many efforts for preventing the damages by overcoming the pollution resulting from fossil fuel consumption. Advances in digital technologies and cost reductions in the renewable sources of energy, while eliminating some energy security dilemmas, provide tremendous opportunities for energy transitions. In the sustainable development scenario, in addition to the direct use of hydrogen and renewables, electricity would be one of the few energy sources experiencing an increase in consumption by 2040, where the share of electricity in final consumption, less than half that of today oil, exceeds oil (World Energy Outlook , 2019).

Additionally, in the last decade, regarding the growing knowledge about the hazardous effects of logistics activities, such as transportation which has a considerable impact on the ecological environment, requests for more environmentally friendly practices have increased (Sabet & Farooq, 2022).

The lack of optimized routing and territorial planning leads to increased transportation costs, even though exact cost is not recorded at this stage. Vehicles with different carrying capacities are dispatched without an integrated plan that matches vehicle size with demand levels, potentially resulting in underutilized capacity or unnecessary additional trips (Javanpour et al., 2025). These inefficiencies increase fuel consumption and greenhouse gas emissions, contributing to air pollution and traffic congestion, particularly in urban areas. Such environmental effects negatively influence public health and the overall quality of life of society (Asghari, Mohammad, Al-E-Hashem, & Al-E-Hashem Assistant, 2020).

Despite the availability of optimization models, there is a limited application of integrated transportation and vehicle routing frameworks that explicitly consider sustainability aspects in the beverage industry, particularly in developing-country contexts (Arslan & Ergun, 2019). The route Moha Soft Drink shows that un-integrated approach which needs structured support

frame work that can improve routing efficiency, reduce environmental impact, and enhance overall distribution performance(Javanpour et al., n.d.-b) .

Transportation, transshipment, assignment, and vehicle routing problems are analytical tools that we can use for optimizing distribution systems (Liu et al., 2023) . In real world scenario, these problems are very interconnected, particularly in difficult distribution networks such as beverage supply chains. Nevertheless, applying these models in only can't guaranty because of complexity of real-world logistics systems, where cost efficiency, environmental sustainability, and resource utilization should be addressed together (Sabet & Farooq, 2022).

Beverage industries face additional distribution challenges due to geographically dispersed markets, frequent demand fluctuations, and the need for timely delivery to retailers. Inefficient routing and poor coordination of shipment flows increase transportation costs, reduce operational performance and also increase pollution. Studies on soft drink and beverage distribution indicate that the absence of structured routing and transshipment planning leads to excessive travel distances, poor vehicle utilization, and inconsistent service levels (Herrera J. L., 2022)

Moha Soft Drink Plant operates a distribution system that serves Addis Ababa as well as other cities. However, from an operational perspective, the existing distribution system does not integrate key decision elements such as transportation flows, vehicle routing, transshipment considerations, and vehicle capacity constraints into a unified framework. Decisions related to routing, vehicle assignment, and shipment quantities are made independently, without a systematic optimization approach capable of handling variable distances, costs, and demand conditions. This fragmented decision-making limits the plant's ability to improve efficiency and sustainability simultaneously (Javanpour et al., 2025) .

Based on preliminary interviews conducted with feet coordinator, area sales manager and researcher's observation during the initial assessment, Teklehaymanot and Dessie plants were selected due to the significance of the business and currently having trouble getting their products to customers. The Dessie plant is in a good location, but it doesn't have enough capacity to meet all of its regional demand on its own. In the past few years, transportation problems and security concerns along some routes have also made it harder to move goods from Dessie to markets near Addis Ababa and the Shewa region. Because of these problems, it is now easier and more reliable to supply some of these markets from the Teklehaymanot plant instead. Because of

this situation, two plants must work together to serve overlapping markets while dealing with capacity and route limits.

## 1.3 Research Questions

i. What is the optimal transportation cost of the company's existing distribution network using a transportation optimization model?
ii. Where should distribution center be located, using the center of gravity method, to improve efficiency and responsiveness of the distribution network?
iii. What are the minimum total transportation cost the redesigned distribution network when distribution center are incorporated using transshipment optimization model?
iv. What is the minimum transportation cost of the redesigned distribution network when customer deliveries from the distribution centers are optimized using the Clarke and wright saving vehicle routing algorithm?
v. How do the transportation model, transshipment model, and vehicle routing approach compare in terms of total transportation cost and distribution efficiency?

## 1.4Objective of the Study

### 1.4.1 General Objective

The general objective of this paper is to design integrate Transportation Network for moha soft drink industry using Transportation, Transshipment and Vehicle routing optimization models to minimize transportation cost ,reduce carbon emissions, enhance the sustainability of the distribution network .

### 1.4.2 Specific Objective

- To determine optimal transportation cost of the company's existing distribution network using a transportation optimization model?
- To identify optimal location of distribution center using the center of gravity method to improve efficiency and responsiveness of the distribution network?
- To determine the minimum total transportation cost the redesigned distribution network when distribution center are incorporated using transshipment optimization model?

- To determine the minimum transportation cost of the redesigned distribution network when customer deliveries from the distribution centers are optimized using the Clarke and wright saving vehicle routing algorithm?
- To compare transportation model, transshipment model, and vehicle routing approach in terms of total transportation cost and distribution efficiency?

## 1.5 Significance of Study

This research held significance for several reasons. By route optimization, it aims to improve sustainability through the application of transportation and transshipment models. By evaluating alternative routing options and identifying the list cost distribution plan, the study helps make informed decisions on route selection and distribution structured.

Furthermore, the finding improves practical insight to reduce fuel consumption, improve vehicle utilization and reduce operational cost.

For other beverage industries facing high volume and time sensitive distribution challenge this research can be used us blue print that can be replicated and used.

Simultaneously, the study benefited to the surrounding society by improving quality of life, reduce greenhouse gas emission and also lower noise pollution in residential areas near distribution depots, thereby providing that distributional efficiency can actively support public well-being.

For academic community, this research contributes to the existing literature by illustrating how transportation, transshipment models and vehicle routing can be effectively applied with in the Ethiopian beverage distribution context.

## 1.6 Scope of the Study

This research will focus on sustainable transportation network design of Moha soft drink (Teklehaymanot plant and Dessie plant) analyzing distribution using transportation, transshipment and vehicle routing models. The scope includes the evaluation of the existing shipment routes, supply points, demand points, and potential intermediate nodes within the distribution network. The analysis is limited to transportation cost, routing structure, shipment allocation, and the potential use of transshipment points. These models are selected because real world distribution systems have many demand and supply locations, limited vehicle capacity, and the need to move goods quickly across a network. The Traveling Salesman Problem only

looks at one route and doesn't take into account real world limitations. On the other hand, transportation, transshipment, and vehicle routing models offer a more complete and realistic way to improve logistics operations. So, using them in this study makes the actual distribution system easier to understand and helps people make better decisions about how to cut costs and make the network work better.

## 1.7. Limitation of the Study

There are several limitation related to the assumption of optimization models. The transportation transshipment and vehicle rout optimization model assumed fixed transportation cost ,demand and vehicle capacity ,which may differ from real world conditions. To reduce it the research used recent data obtained from relevant experts. In addition, Clarke and wright saving algorithm was used to optimize the vehicle routing .Although this heuristic method does not guarantee the best possible route solution when it comes to complex transportation network such as global transportation network .to mitigate this limitation, the current distribution data and operational information were incorporated in to the analysis to ensure that the optimized route remain practical and applicable to the study.

## 1.8 Organization of the study

This research, Integrated Sustainable Transportation Network Design using Transportation, Transshipment and Vehicle routing optimization: A Case study of Moha soft drink industry S.C, contain five chapters. The first chapter is an introduction that includes background of the study, research question, objectives of the study .chapter two contains literature review and their gap. The third chapter describe the methods that are used in the study .Chapter four is where analysis is done and interpret. Finally, chapter five summarize, recommend and conclude based on the analysis on chapter four.

# CHAPTER TWO

## Introduction

This chapter covered empirical literature review, theoretical literature review on transportation, transshipment and vehicle routing relation to sustainability .it is structured in to four literature parts: a theoretical frame work, empirical, summary and gap.

## 2.1 Theoretical Literature Review

### 2.1.1 System Theory

The two key feature of an organization that are stated on system theory are :a) that they are in a system which every action is informed, shaped and sometimes determined. b) the inter dependence between the part of the system shows that change in one area result change in another (Cafferkey., 2019 ).

The goal of system theory is to explain the interaction between an organization environment and its part .system is formed based on the pattern that results due to their interaction. Different system are result of different pattern and system theory 3 relationships ,every system is differ from one another .in another word ,components of social organization have different intention and will .In general ,system theory targeted on three levels of observation :environment ,social institution and the community in the organization . To accomplish this goal there are different strategies .one of them is general phenomena .for example ,it is common on social organization that interact and share the same environment develop in to interdependent relationship (Muema & Mungai., 2025)

#### 2.1.1.1 Overview of Transportation Systems in Supply Chains

Relocation of material from one location to the another is called transportation .in industrial perspective, expense to relocate product from supplier to the market .transportation system is one of the most important economic activity in logistics .using transportation system products move to the destination on time and effectively to add value under list cost principle .transportation has effect over all activity of logistic which include production and sales (Rajish et ai, 2015).

Transportation impacts logistics performance, efficiency and effectiveness .which is the major factor given that transportation is responsible for majority of cost of logistic. Minimizing transportation cost will significantly reduce the total cost of logistics (Shilpa Parkhi, 2014).

Decision related to transportation management include funding the optimized route ,finding the best mode of transportation and delivering goods on time (Makabira, 2022).Half of the logistics cost on average is consumed by transportation. The retailer gain competitive advantage by effective transportation facility .currently the distribution network is influenced by retailer the distribution to retailer is done using road mode transportation. Managing distribution center and transportation network will significantly reduce cost.(Shilpa Parkhi, 2014) (Makabira, 2022). For logistic distribution, optimized rout can reduce transportation cost and improve productivity. According to researcher, "transportation cost should relate the distance between the origin and the final destination, and such cost should include drivers payment, maintenance cost and inventory cost'' (Shilpa Parkhi, 2014).

Unfortunately, transportation is sometimes the forgotten element in a supply chain model. Nodal activities, such as fabrication, assembly, and inventory, are emphasized when the focus is on conversion of components to sub-assemblies and finished products. But how do those materials actually get from one node to the next? Can the timing or scheduling of those movements of goods be improved?

We feel that transportation should be accorded the same importance as the other operations management activities. The benefits of good production-inventory decisions can be easily overwhelmed by neglecting the economies of scale available in the various transport modes. Two of those modes, air and water, are the only ways to move goods between non-contiguous countries. Water transportation and air freight are automatically "global" in that Context (Matuk, 2025).

### 2.1.2 Sustainable Transportation in Supply Chains

ln the last decade, regarding the growing knowledge about the hazardous effects of logistics activities, such as transportation which has a considerable impact on the ecological environment, requests for more environmentally friendly practices have increased. The European Union (EU) has targeted a 40% reduction in greenhouse gas (GHG) emissions by 2030 compared to 1990.This is a challenge for the transportation sector, which is responsible for 20% of total GHG emissions, according to the European Environment Agency (2014). Moreover, with increasing urbanization, air quality in cities is emerging as a hot topic, which has led to a debate over the

prohibition on internal combustion engine vehicles (ICEVs) in European metropolitan areas (Asghari, 2020).

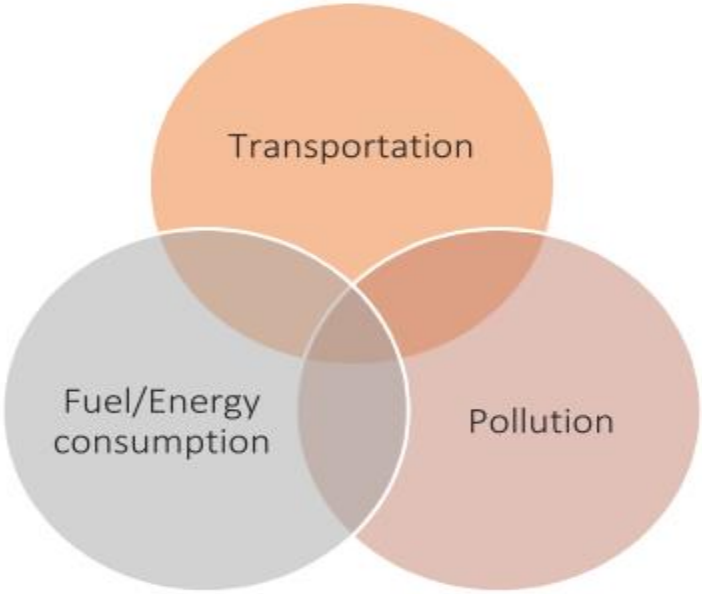



**Figure 1 Three structured review term categories of Green VRP.**

### 2.1.3 Optimization Theory

Optimization is minimizing the value function of variable, that is subjected to constraint on the subject of those variable .This method can be applied on many area of engineering, science and also economics.it has many class and subclass (e.g. integer and linear programming) each provide formulation and application .mathematics is applied in optimization in order to formulate, draw algorithm and analysis their properties. The research include the existence and characterization of the solution; solution stability under perpetration of the problem data and also duality, which gives another option for the given formulation. Algorithms is sequential iterative and also sequence of candidate and solution for optimization converge to solution for the problem on hand and also rigorous frame work that contain heuristic to guide decision. For example on linear programming list of validate is choice based on the objective. Along with mathematical study and imagination, a good objective and demand of the application area. Development of software to implement these algorithms requires many other areas of expertise to be brought to bear, involving broader mathematical knowledge and software engineering

expertise. The mathematical issues include the vagaries of finite-precision arithmetic, robustness in the face of formulations, the interface with numerical linear algebra, and parallel implementation, among many others. Engineering issues (some of which can also be analyzed mathematically) include management of hierarchical memory and data movement (Wright, 2025).

### 2.1.3.1 Definition and Purpose of the Transportation Model

The transportation model deals with a special class of linear programming problem in which the objective is to transport a homogeneous commodity from various origins or factories to different destinations or markets at a total minimum cost (Panneerselvam, 2012)

### 2.1.3.2Assumption of the Transportation Model

Linear programming model one of the mode that associate algorithm that can math to the current and future industrial application .while making decision it consider all the drivers and load at the same time. Human dispatcher tends to done in to simple pieces. Breaking problem what load should be signed to the driver? What is the capable driver that should assigned for the load? assigning the right load to the right driver is beyond the problem that can be solved by most of the people .News about the model spread quickly so that other career want to employee this optimization for load matching problem. At 1980s and 1990s this technology sold by a small cottage industries (taylor, 2007).

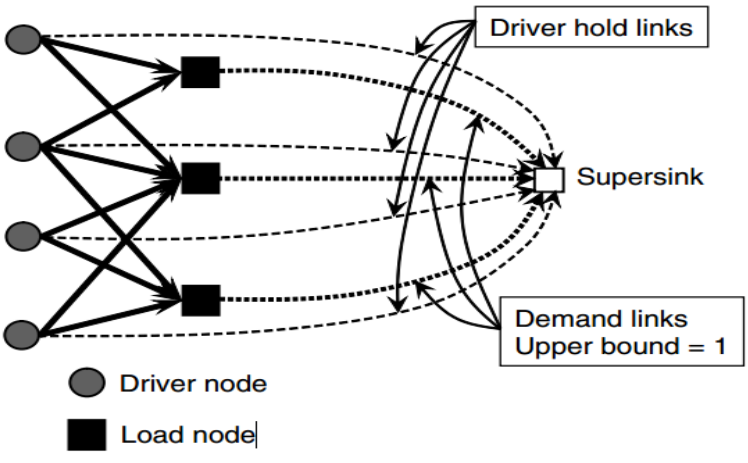



**Figure 2 Network model for driver assignment model**

### 2.1.4 Conceptual Underpinning Related To Sustainability and Route Optimization Distribution Using Transportation, Transshipment Model and Vehicle Routing

Transshipment models expand on transportation models by permitting intermediary nodes to facilitate consolidation and better flow coordination. Transportation models seek to distribute shipments between supply and demand points in an effective manner by minimizing overall transportation costs (Panneerselvam, 2012). Fuel consumption, distribution costs, and maintenance costs are significantly impacted by these models' emphasis on efficient vehicle deployment, distance reduction, and optimal resource usage (Heizer, 2017). Effective transportation and transshipment planning greatly improves cost efficiency, especially in intricate and multi-echelon distribution networks, according to empirical and analytical research (Suarez et al., 2021).

By identifying the most effective vehicle routes and delivery sequences inside distribution networks, route optimization enhances this framework even more. Vehicle Routing Problem (VRP) models and their variations are frequently used to increase fleet utilization, delivery reliability, and route efficiency, which results in significant operational cost savings (Rajish et ai, 2015). Routing and transshipment decisions can now more accurately represent real-world logistics environments thanks to recent developments that take unpredictability and dynamic demand situations into account (Bharti, 2024). According to systems theory, in order to achieve sustained cost minimization and overall supply chain performance, transportation, routing and transshipment decisions must be optimized collectively rather than separately (Cafferkey., 2019 ).

### 2.1.5 Impact of Using Transportation and Transshipment Model

Transshipment is transportation of goods from the source point to the final destination through the distribution center (transshipment node).Distribution point in this case act as distribution center and warehouse in the industry, because supply chain is one of critical factor industrial process. In many research, transshipment is optimized to find the least cost (Zhao, 2025).

### 2.1.6 Transshipment Model

#### 2.1.6.1Concept and Definition of Transshipment

Transshipment study assumed that all source and distribution point is shipping at the same time .Transshipment is more used than transportation problem.it is known that transportation is

relocation of product from the origin to directly to the final destination .However ,In transshipment problem between the origin and the destination there is transshipment node .This transshipment node known as distribution center ,connecting source point and final destination(Herrera J. L., 2022).

#### 2.1.6.2 Why Transshipment is used in the Supply Chain

Transshipment plays a critical role in modern supply chains because it allows companies to move goods efficiently between different locations before they reach their final destination. This optimization algorithm helps to reduce transportation costs, improve delivery speed, and improve flexibility based to customer demand. By consolidating shipments at transshipment points, organizations can optimize the use of vehicles, reduce unnecessary empty trips, and balance demand and supply across multiple locations (Suarez et al., 2021).

For example, in multi-product distribution networks, transshipment allow companies to move stock from one warehouse to another to customer demand fluctuations without waiting for new shipments from suppliers. This not only reduces stock out but also minimizes carrying costs and overall transportation (Mutovkina N, 2025).

### 2.1.7 Route Optimization

#### 2.1.7.1 Concept of Route Optimization

Route optimization refers to the process of finding the best delivery paths in a distribution network to minimize total transportation cost which is the sum of all variable and fixed expense , delivery time, and resource utilization while satisfying operational constraints (e.g., vehicle capacity, time windows, demand). In modern logistics, a firm employs algorithmic routing models, and computerized methods to achieve optimal or near-optimal routes.

A 2023 study was on last-mile delivery that developed an optimization model for the vehicle routing problem applying heuristic algorithms such as local search. The study showed that applying these optimization techniques make the route more cost-effective, making them particularly suitable for complex urban logistics environments which is delivery efficiency is critical (Veer Tiwari, 2023).

In 2024, an integrated vehicle routing model was made in order to optimize the distribution of agricultural products in retail chains. This study introduced a mainly two objective optimization

approach that can simultaneously minimizes transportation cost and also reduce fuel consumption using real distribution data. The results provide that applying multiple objectives in route optimization leads to more sustainable and practical logistics solutions (Fernando, 2024) .

#### 2.1.7.2Route Selection Technique

There are several factor for Route selection, including the distance between nodes, vehicle capacity constraints, traffic conditions, lead time , demand patterns, and delivery reliability. These factors directly or indirectly affect routing efficiency, fuel consumption, and overall cost of distribution, making them critical considerations in logistics planning (Hua, 2014). Effective route optimization must consider route optimization to minimize transportation costs while ensuring reliable and timely delivery across the supply chain (taylor, 2007).

#### 2.1.7.3Route Optimization Technique

Some of the research in logistics and supply chain management has used a wide range of route optimization techniques, such as classical linear programming models, meta-heuristic algorithms, and hybrid optimization approaches. These researches also used Vehicle Routing Problem (VRP) and its variants such as the capacitated VRP and VRP with time windows to optimize fleet operations and distribution networks (Panneerselvam, 2012) (Rajish et ai, 2015). These models improved decision-making and on time delivery that can be related to route efficiency, vehicle utilization, and cost reduction.

Recent advances improved traditional VRP models by reducing uncertainty and variability in travel time and demand. Modern optimization and intelligent routing approaches now consider dynamic conditions of the real world environments (Bharti, 2024). Such developments support more reliable and adaptive route optimization, contributing to reduced transportation costs and improved supply chain performance (Fernando, 2024).

For example, the study “An Integrated Vehicle Routing Model to Optimize Agricultural Products Distribution in Retail Chains” demonstrates that combining vehicle routing optimization with strategic distribution scheduling achieved a 19% reduction in distribution cost and 24% fuel savings, evidencing the powerful cost minimization potential of integrated models Science Direct. Another study modeling last-mile delivery via VRP with capacity constraints shows that optimized routing and shipment allocation reduces operational cost significantly compared with naive dispatch methods (Rajish et ai, 2015).

Moreover, in cases where transshipment (intermediate depot) is combined with routing especially under demand variability and dynamic network constraints  advanced models (e.g., hybrid optimization with inventory-routing and transshipment) yield cost savings through load consolidation, reduced empty trips, and better flow balancing (Heizer, 2017) (Panneerselvam, 2012).

#### 2.1.7.4Relationship between Routing and Sustainability

Logistics institute reduce total cost and carbon emission using optimization of resource and adjust vehicle routing (Naderipour M, 2016)measured, evaluated and minimized of CO2, NOx, and CO as three important emissions (that come out from vehicles) in the open time dependent vehicle routing problem (OTDVRP), and identified the order of distribution and the speed of travel can significantly reduce greenhouse gas emissions. With the minimum carbon emission as the objective function, in addition to the optimization of the enterprises to reduce carbon emissions, the government also plays a crucial role, such as implementing carbon tax and carbon trading. Some scholars developed single-objective optimization models considering distribution and carbon emissions costs. (Li Y et al, 2023) and also used the carbon tax to calculate the cost of carbon emissions.  Some scholars built multi-objective models to minimize costs and carbon emissions. (Zulvia FE, 2020) proposed a Mult objective green vehicle routing problem model for perishable products which optimizes the operational cost, deterioration cost, carbon emissions and customer satisfaction (Liu Y. T., 2025).

### 2.1.8 Sustainability Approaches in Logistics

The environmental impact of the early transportation solutions was not immediately apparent, but already in the 1870s concerns were raised about the noxious smoke produced by steam locomotives. The very first underground railway, the City and South London Railway, actually prohibited the use of steam power, favoring electric locomotives. In the 1940s a phenomenon referred to as smog started appearing in Southern California and Pennsylvania, causing stinging eyes and respiratory irritation. Haagen-Smit showed that the smog resulted from a photochemical reaction of unburned hydrocarbons, ground-level ozone and nitrogen oxides (NOx), originating from vehicle exhaust and industrial power generation. This ground-breaking discovery eventually led to the first vehicle emissions control system, positive crankcase ventilation, being introduced in 1961 in the State of California. Six

Years later the California Air Resources Board (CARB) was created and the Environmental Protection Agency (EPA) followed in 1970. In Europe, the European Economic Community (EEC) established rules, initially considerably less stringent than those in the United States, introduced in stages by engine displacement (Hergart, 2022).

For example, the study "An Integrated Vehicle Routing Model to Optimize Agricultural Products Distribution in Retail Chains" demonstrates that combining vehicle routing optimization with strategic distribution scheduling achieved a 19% reduction in distribution cost and 24% fuel savings, evidencing the powerful cost minimization potential of integrated models (Rajish et ai, 2015). Another study modeling last-mile delivery via VRP with capacity constraints shows that optimized routing and shipment allocation reduces operational cost significantly compared with naive dispatch methods (Panneerselvam, 2012).

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Therefore, sustainability in logistics is not solely about minimizing shipment allocation it requires simultaneous optimization of route planning, fleet utilization, and flow design.

#### 2.2.5.1 Sustainability Principle

Cost minimization in logistics is achieved by combining optimal allocation models (like transportation or transshipment models) with advanced routing optimization techniques. This dual-approach ensures that not only are shipments allocated efficiently among sources and destinations, but also vehicle routes are optimized to reduce operational expenses.

Therefore, cost minimization in logistics is not solely about minimizing shipment allocation cost it requires simultaneous optimization of route planning, fleet utilization, and flow design.

#### 2.2.5.2 Sustainability through Transportation Model

The objective function of the transportation model is maximizing effectiveness and efficiency of delivery of product. The conditions are: providing each route with one driver and one forwarder (or it can be two drivers replacing each other on long-distance trips. If the delivery is within the city and the cargo is small, then one driver is a route. All at the discretion of the company's

management, but taking into account the need to comply with the work and rest regime of drivers and ensure that each employee of the company works on one specific route (delivery of goods to recipients located on the route) (Matuk, 2025).

In today's business environment, companies are increasingly pressured to operate efficiently and reduce costs. One area where this is particularly true is in transportation, where the cost of truckload transportation can be a significant expense. To address this challenge, many companies are turning to collaboration as a way to optimize their transportation networks and reduce costs. Collaboration has emerged as a promising strategy for achieving this goal, as it allows companies to pool their resources and work together to optimize their transportation networks. This method can highly improve efficiency, reduced relocating costs, and other benefits that can help companies to improve their bottom line (Ozlem Ergun, 2007).

#### 2.2.5.3 Sustainability through Transshipment Model

By facilitating the aggregation and redistribution of products between intermediary nodes within the supply chain network, transshipment significantly contributes to the reduction of transportation costs and greenhouse gas emissions. Organizations can reduce overall trip distance, increase vehicle usage, and attain economies of scale in transportation operations by properly assigning transshipment sites.(taylor, 2007).

#### 2.2.5.4 Case studies in beverage distribution industries

Beverage sector case studies offer real world examples of how transshipment methods and route optimization can lower transportation costs and increase distribution effectiveness. Optimized routing and distribution planning result in reduced fuel usage, increased vehicle utilization, and more dependable delivery schedules, according to research done in soft drink and refreshment industries (Suarez et al., 2021) .These studies highlight how critical it is to match distribution network designs and demand patterns with transportation techniques.

Overall, the results of beverage distribution case studies show how important it is to apply logistics optimization models in real world situations. These illustrations highlight the importance of optimized route and transshipment planning in lowering transportation costs and improving supply chain effectiveness in the beverage industry (taylor, 2007) (Heizer, 2017).

## 2.2 Empirical Literature Review

### 2.2.1 Empirical Literature Reviews on Transportation in Distribution System

Many empirical investigations have demonstrated that increasing the efficiency of distribution and transshipment systems is largely dependent on transportation cost minimization. Researchers have concentrated on double strategies for businesses to reduce expenses without sacrificing prompt and dependable product delivery.

Mutovkina N. (2025) investigated how road transportation systems may be improved by logistics optimization models. By focusing on prompt delivery, excellent transportation quality, and minimizing unnecessary stops or route deviations, the study aimed to increase the efficiency of drivers and forwarders. The study claims that allocating particular drivers and forwarders to predetermined routes enhances operational control and responsibility. The study also took into account various delivery scenarios, such as quick urban deliveries and long-distance excursions that call for two drivers.

In a related study, Ozlem E. (2007) explored how collaboration among companies can help to reduce overall truckload transportation costs. The study highlighted that many companies face high transportation cost when operating independently. By working together and sharing transportation resources, companies were able to improve route utilization and reduce unnassary or unproductive trips. The empirical evidence from the study showed that collaboration leads to lower transportation costs and better overall use of transportation assets, resulting in improved cost efficiency across distribution networks.

Overall, these empirical studies show that both external cooperation and also internal operational improvements can be used to optimize transportation costs. Reducing transportation costs and enhancing the efficiency of transshipment and distribution systems are greatly aided by cooperative transportation tactics, efficient route planning, and optimal driver utilization.

### 2.2.2 Literature on Transshipment in Distribution Network

Transshipment is a critical component of distribution networks because it makes it possible for products to pass through intermediary facilities before arriving at consumers. This strategy helps businesses in managing intricate logistics systems more effectively, reducing transportation costs, and increasing delivery speed.

Wang et al. (2023) studies how multimodal transportation networks can optimize transshipment routes. They demonstrated how learning algorithms may be used to arrange transportation routes with transshipment sites more effectively and efficiently. According to their studies, distribution networks that use a variety of modes of transportation can greatly benefit from intelligent route selection.

Bharti and Varma (2024) focused on transportation and transshipment choices in situations including unpredictability, like shifts in demand. Their research complicated optimization techniques that assist decision makers in discovering trustworthy answers even in uncertain situations. This study emphasizes how critical it is to take uncertainty into account when organizing transshipment operations inside distribution networks.

### 2.2.3 Empirical Studies on Route Optimization Models

The performance of transportation and distribution systems is frequently improved by route optimization models, especially in last-mile delivery operations where cost control and efficiency are critical. Vehicle routing problems (VRP) are the subject of many empirical investigations because they are useful instruments for lowering transportation costs and raising service quality.

Tiwari and Sharma (2023) created an optimization model for the truck routing problem using heuristic techniques like tabu search and local search algorithms in a study on last mile delivery. According to the study, these methods work well for creating more economical and efficient delivery routes, particularly in complicated urban routing where traffic jams and frequent pauses are typical. The findings demonstrated that heuristic based route optimization dramatically lowers operating cost and increases delivery efficiency.

Similarly , Fernando et al. (2024) suggested an integrated vehicle routing model with the goal of maximizing agricultural product distribution in retail chains. Using real world distribution data, the study presented a two objective optimization method that sat the same time reduces fuel usage and transportation expenses. The results showed that integrating several goals into route optimization produces more practical and sustainable logistical solutions. This method not only increases economic effectiveness but also promotes environmental sustainability.

Overall, these empirical investigations show that route optimization models are important for improving transportation efficiency in distribution networks. Organizations can get better service

quality, lower costs, and more sustainable logistics operations by utilizing complex optimization approaches and taking into account different performance objectives.

## 2.3Literature Review Summary

Previous studies shows supply chain management and logistics are crucial for lowering transportation costs and increasing productivity. To optimize distribution processes and create more sustainable logistics operations, many researchers have created various routing, transportation, and transshipment models. In order to address difficult delivery and last mile distribution problems, recent research also applied complex optimization techniques, such as artificial intelligence and uncertainty based models. Furthermore, supply chains can be understood as interconnected systems where decisions made in one sector have an impact on the whole network by applying Systems Theory. However, the majority of this research concentrates on certain industries or set circumstances, which restricts their applicability in many supply chain contexts.

## 2.4Gap in Previous Studies

There are still a lot of gaps in existing literature on supply chain optimization, logistics, and transportation. Larger system level interactions that take place within supply chains are still paying little attention in favor of route efficiency and sustainability. Because systems theory is mostly studied conceptually rather than practically, it is rarely included into logistics optimization models. Furthermore, because they rely on static data and fixed assumptions, many optimization models fail to replicate the dynamic and unpredictable nature of real supply chains. Despite the recent establishment of complex optimization techniques and artificial intelligence, their application remains fragmented and industry-specific, limiting flexibility and scalability. Furthermore, real time decision making and sustainability are not sufficiently addressed by present models. These make it clear that a comprehensive, system oriented logistics optimization framework that integrates state of the art technology, dynamic data, and comprehensive performance indicators is necessary to facilitate modern supply chain decision-making.

# CHAPTER THREE

## Introduction

This chapter contains the research approach, research design, target population and sample, data source, data collection technique, validity and ethical issue.

## 3.1 Description of the Study

This study asses factors that are related to integrating sustainable Transportation Network Design using Transportation, Transshipment and Vehicle Routing optimization. The case study was done at Moha Soft Drink Teklehaymanot and Dessie Plant. A mixed-methods approach using quantitative component and qualitative component.

## 3.2 Research Approach

**1. Quantitative Approach** is essential for modeling, measuring, and optimizing key performance indicators such as transportation costs, vehicle utilization rates, fuel consumption, travel distances, greenhouse gas emissions, and overall distribution efficiency**.**

**2. Qualitative Approach** is necessary to capture contextual realities, operational constraints, stakeholder perceptions, practical challenges, and decision-making behaviors that are difficult to quantify but significantly influence the feasibility and successful implementation of optimization models.

## 3.3 Research Design

A research design encompasses deliberate choice on the uses of data collection and data source methodologies (Kumar, 2011).

To investigate key factors related to integrated Sustainable Transportation Network Design using Transportation, Transshipment and Vehicle Routing optimization. The case study is conducted at Moha Soft Drink Teklehaymanot and Dessie Plant; the researcher employed an explanatory and descriptive research approach. In light of this, Insights are gathered from Moha plant distribution coordinator, sales coordinator and fleet coordinator after that the gathered insight precedes to Examines the relationship between sustainability and transshipment, transportation and VRP.

## 3.4 Population and Sampling

### 3.4.1 Population

The target population for this study compromises specialized logistics professionals with in Moha Teklehaymanot and Dessie plant S.C. This includes the head office sales coordinator, plant sales coordinator and fleet coordinator from Moha Teklehaymanot and Dessie plant S.C, totaling 10 individuals. Therefore no statistical sample calculation formula was applied and 10 population members (2 from had office and 4 from each plant) were targeted for interview to ensure comprehensive data collection.

### 3.4.2 Sampling Design

The study employ no probability sampling technique, specifically purposive sampling .this method was selected for its practicality and the sample size of the study. Purposive sampling is beneficial since the information gathered is rich and closely related to the study objective, resulting more insightful and more specific.

In the context of this study, purposive sampling was employed to collect primary data from Moha Teklehaymanot and Dessie plant.

## 3.5 Measurement Design

- **Qualitative Feedback**: sales coordinator and plant distribution coordinator feedback is deemed reliable due to their direct retailer and distribution interactions.
- **Cross-Country Data**: Publicly available economic databases and industry reports ensure data reliability and validity.
- **Internal beverage Data**: Financial and operational data from Moha's internal systems provide robust metrics.

## 3.6 Data Sources and Collection Procedure

Both primary and secondary data source are used in the investigation .primary data were collected from employees through structured and semi structured interview.

Secondary data were collected from the industry report, schedule, manual, published and In order to support the findings obtained from the interview; a review of related literature was conducted

to compare the alignment of the research findings with previous studies and enrich the overall findings.

## 3.7 Model Specification

The research uses a combination of qualitative and quantitative models to integrate Sustainable Transportation Network Design using Transportation, Transshipment and Vehicle Routing optimization in the case of to Moha Soft Drink industry.

### 3.7.1 Qualitative Analysis Model Specification

The qualitative analysis gathered feedback from sales and fleet coordinator via interview. The analysis assessed sustainability based on:

- Inconveniences due to optimal route requirements,
- Environmental perceptions,

## 3.9 Data Analysis

### 3.9.1 Transportation Model

Transportation models can be solved using spreadsheets like Microsoft Excel. (which can be downloaded from the text web site). Notice in this screen that the formula for the total transportation cost is embedded in cell C10 shown on the formula bar across the top of the screen. Total cost is computed by multiplying each cell cost by each value in cells C5:E7inclusive that represent the shipments (currently 0) and summing these products. Formulas must also be developed for the supply and demand rim requirements. Each distribution center can supply only the amount it has available, and the amount shipped to each plant must not exceed what it demands.

Similar summation formulas for the other distribution centers and each plant are also developed. If you click on cells G5,G6,G7,C9,D9,and E9,would see these formulas on the formula bar. Since this is a balanced transportation problem, where total supply equals total demand (i.e.,600 tons), then each amount shipped from each distributor equals the available supply, and each amount shipped to each plant equals the amount demanded. These mathematical relationships are included in the “Solver “screen accessed from the “Data “menu on the toolbar. The “target “cell containing total cost is C10,and it is set equal to “min”since our objective is to minimize cost.

The “variables” in our problem representing individual shipments from each distributor to each plant are cells C5 to E7 inclusive. This is designated as “C5:E7.”(Excel adds the $s.) The constraints mathematically specify that the amount shipped equals the amount available or demanded. For example, “C9 C8” means that the sum of all shipments to Chicago from all three distributors, which is embedded in C9, equals the demand contained in C8. There are six constraints, one for each distributor and plant. There are two more requirements. First, “C5:E7 0.” This specifies that all the amounts shipped must be zero or positive. This can be accomplished by adding this as a constraint, or (as is the case here), clicking on “Options” and then activating the “Assume non-negative “button. Also, on the “Options “window activate the “Assume linear models “button. Once all the model parameters have been entered into the solver, click on “Solve. “The solution is shown on the Excel screen. (Robert s, russel ,Bernared w,Taylor, 2011)

### 3.9.2 Transshipment Model

Transshipment models expand on transportation models by permitting intermediary nodes to facilitate consolidation and better flow coordination. Transportation models seek to distribute shipments between supply and demand points in an effective manner by minimizing overall transportation costs (Panneerselvam, 2012).

The following steps are used to solve the transshipment model

#### 3.9.2.1 Identification of Nodes

Identifies all transshipment nodes, and demand nodes in the distribution network. Supply nodes are sources of goods, demand nodes are destinations, and transshipment nodes act as intermediate distribution centers (Januardi, 2020).

#### 3.9.2. 2 Decision Variables

Define the decision variables representing the quantity of goods transported from node a to node z.

#### 3.9.2.3 Objective Function

Formulated the objective function to minimize total transportation cost between all nodes in the network (Weckenborg, 2024).

### 3.9.2. 4 Constraints Formulation

Developed the following constraints

- Supply constraints at source nodes
- Demand constraints at destination nodes
- Flow balance constraints at transshipment nodes (total inflow = total outflow) (Naderi, 2020).

### 3.9.2.5 Model Conversion

After that Convert the transshipment model into transportation model by creating a transportation tableau including all nodes (sources, transshipment points, and destinations).

### 3.9.2.6 Initial Solution

Found an initial feasible solution using methods such as North-West Corner Method, Least Cost Method, or Vogel's Approximation Method.

### 3.9.2.7 Optimal Solution

Test the optimality of the solution using the MODI (Modified Distribution) method to obtain the minimum transportation cost.

### 3.9.2.8 Interpretation

Analyze the results and determine the optimal shipment quantities between sources, transshipment points, and destinations.

### 3.9.3Clarke & Wright Method

This algorithm is based on a savings concept. The distance matrix identifies the distance between every pair of locations to be visited. If the transportation costs between every pair of locations are known, the cost can be used in place of distance. The distance dij on a grid between a point i with a coordinates (xi,yi) and a point j with a coordinate (xj, yj) is evaluated as:

$$\mathbf{d_{ij}}=\sqrt{(\boldsymbol{xi}-\boldsymbol{xj})^2}+(\boldsymbol{yi}-\boldsymbol{yi})^2$$

where: d$n$ = Distance

x= Latitude or lines of latitude on Earth

y= Longitude or the Earth's meridian

I. Starting solution: each of the n vehicles serves one customer.

II. For all pairs of nodes i,j, calculate the savings for joining the cycles using edge [i,j]:

$$\mathbf{Sij = C0i + C0j - Cij}$$

III. Sort the savings in decreasing order

IV. Take edge [i,j] from the top of the savings list. Join two separate cycles with edge [i,j], if

a) The nodes belong to separate cycles
b) The maximum capacity of the vehicle is not exceeded.
c) i and j are first or last customer on their cycles and Repeat 4 until the savings list is handled or the capacities don't allow more.

## 3.10 problem formulation

This study evaluates key factors related to Sustainable Transportation Network Design (The Application of Transportation, Transshipment and Vehicle Routing Problem Solving Algorithms The case study is conducted at Moha Soft Drink Teklehaymanot and Dessie Plant. A mixed-methods approach using quantitative component and qualitative component.

The distribution network is formulated as a Vehicle Routing Problem, where vehicles depart from a depot to serve multiple customers while minimizing transportation cost.

### 3.10.1 Decision Variables

Let:

- Xij = quantity transported from plant iii to destination j

Where:

- i∈{D, T}
  - D = Dessie Plant
  - T= Teklehaymanot Plant
- j=1,2, 3… n (all destinations shown in your diagram)

### 3.10.2 Parameters

- Cij = transportation cost per unit from plant I to destination j

- Si= supply (capacity) of plant i
- Dj= demand at destination j

### 3.10.3 Objective function

Minimizing the total transportation cost

- Minimize $\mathbf{Z=\sum_i \sum_j CijXij}$

### 3.10.4 Constraints

**(A) Supply Constraints (Plants)**

Each plant cannot ship more than its capacity

- $\mathbf{\sum_j XD_j \leq SD}$

**B) Demand Constraints (Destinations)**

Each destination must receive its required demand

- $\mathbf{\sum_j X_{ij} = D_j \forall_j}$

So the LP becomes

- $\mathbf{Z=C_{D,\,Lalibela} X_{D,Lalibela} + C_{T,Lalibela} X_{T,Lalibela} + \dots}$

### 3.10Validity

Validity refers to the ability of the instrument to measure what it is designed to measure. (Saunders, 2009) state that validity is the strength of conclusions, implications, or propositions drawn from the research. It is concerned with whether an instrument accurately measures what it is intended to measure. To ensure the validity of the research instrument, the researcher worked closely with the adviser as an expert to evaluate and confirm the appropriateness of the instrument. In addition, the survey and interview were developed based on a comprehensive review of related literature and the research framework to ensure the validity of the results.

### 3.11 Ethical Consideration

The AAU SOC will formally correspond with Moha Teklehaymanot and Dessie Plant through an official letter to obtain authorization to conduct the research prior to the commencement of collecting data. Informed consent was obtained from all participants before the research instrument is distributed, and only those who voluntarily agree to participate were included in the

study as respondents. During the data collection process, interviewers were clearly explained the objective, the scope and the outcome of the study. All information provided by the respondents was handled confidentially and ethically to ensure that their original views are not misrepresented. Furthermore, respondents will be assured that the data they provide were used solely for academic research purposes. Confidentiality will be maintained throughout the research, as no individual participant will be identified in any reports or publications.

## 3.12Expected result

It is anticipated that the research demonstrate to Sustainable Transportation Network Design using transportation and transshipment models and the expected result would be included:

- Identifying the current distribution optima route and designing sustainable transportation network.
- Developing transportation, transshipment and VRP model that determine the optimal route.
- Exploring alternative routing option that may reduce the pollution through transportation, transshipment model.

# CHAPTER FOUR
# DATA ANALYSIS, RESULTS AND DISCUSSIONS

## 4.1 Introduction

This chapter deals with analysis and interpretation of data collected to assess the current transportation and distribution system of Moha Soft Drink S.C. (Teklehaymanot and Dessie Plants). Both qualitative and quantitative data analysis methods were applied.

The qualitative data were collected through semi-structured interviews from supply chain coordinators, fleet coordinators, and sales coordinators. The quantitative analysis was conducted using Microsoft Excel and Solver to apply Transportation, Transshipment, and Vehicle Routing Problem (VRP) models.

The findings are organized into two main sections:

1. Analysis of the current distribution system
2. Optimization model results and sustainability comparison

## 4.2 Qualitative Analysis of the Current Distribution System

### 4.2.1 Route Structure and Distribution Network

The geographical coverage of the distribution network of Moha Soft Drink S.C., which originates from the Teklehaymanot Plant and the Dessie Plant, covers a wide geographical area that includes Addis Ababa and various regional towns. The products are transported from the plants to the distributors, agents, and retailers through various transportation routes. However, according to the responses of the interview, the routes are not fully optimized, and they are assigned based on demand location and experience.

The current distribution structure for both plants is illustrated in **Figure 3**, which shows the transportation routes connecting the production plants to their respective market areas.

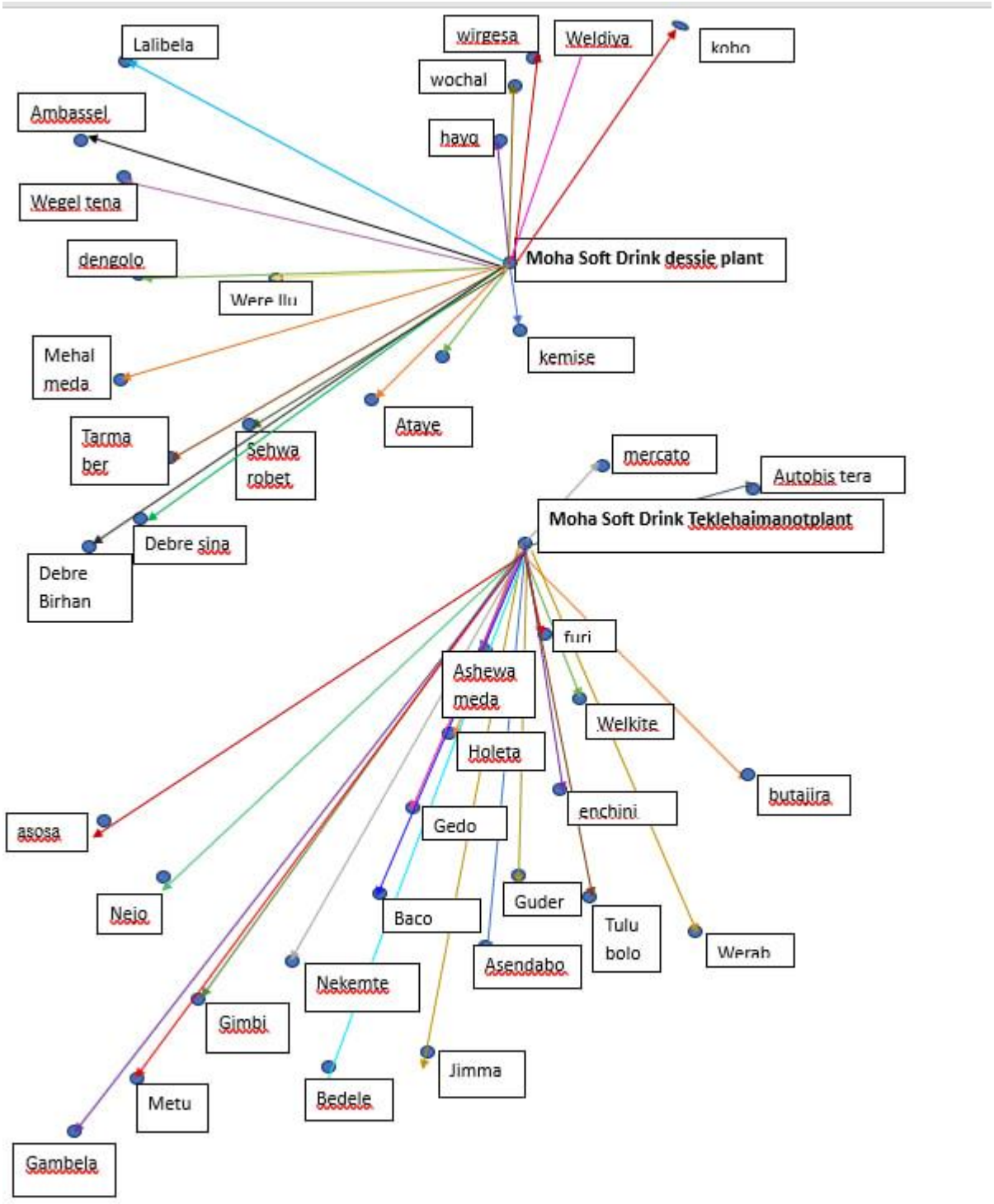



**Figure 3 Current distribution route of Moha Teklehaymanot and Dessie plant**

### 4.2.2 Vehicle Fleet and Capacity Utilization

The type of vehicle fleet used for the transportation of goods for the purpose of distribution is an important factor that affects the efficiency of the transportation system. Based on the interview results, it is evident that the company uses a combination of company-owned vehicles and agent-owned vehicles for the transportation of goods to various destinations.

The most common vehicles used for the transportation of goods include medium and large delivery vehicles, which are used for the transportation of beverage crates. The carrying capacity of these vehicles depends on the size and type of vehicle used for the transportation process. Larger vehicles are used for long-distance transportation, while smaller vehicles are used for transportation within the urban area.

Based on the interview results, it is evident that the number of vehicles used for transportation at the Teklehaymanot Plant depends on the daily demand for beverages. The company uses more vehicles for transportation purposes during holidays and high-temperature seasons, as these are the times when demand for beverages is high.

Despite the availability of multiple vehicles, interview responses suggested that vehicle capacity is not always fully utilized. In some cases, vehicles may depart with partial loads due to urgent delivery requirements or imbalanced demand distribution across routes. This underutilization contributes to increased transportation costs and reduced operational efficiency.

**Table 1 Moha Teklehaymanot and Dessie plant vehicles and their capacity**

| Type Of Vehicle | Vehicle Capacity (per case ) | Amount(car)Teklehaymanot | Amount(car) Dessie |
|---|---|---|---|
| LDV | 300 | 6 | 4 |
| MDV | 525 | 13 | 9 |
| | 625 | 2 | 4 |
| HDV | 2000 | 8 | 2 |
| | 1000 | 2 | 1 |
| | 1716 | 2 | 1 |

### 4.2.3 Route Planning and Vehicle Assignment Practices

The task of planning activities related to transportation and assigning vehicles to routes is mainly the responsibility of the supply chain coordination team and also fleet management department. As indicated by the respondents, the task of planning routes is normally undertaken on a daily basis depending on the volume of customer orders received and the availability of vehicles.

At present, the assignment of routes is mainly done manually through the use of experience and basic planning tools such as Microsoft Excel spreadsheets. The process of planning involves analyzing customer orders and assigning vehicles to routes depending on the location of the customers.

However, due to the lack of dedicated route optimization software, transport planners have to depend on their own judgment and experience in taking decisions. Although such a practice allows for greater flexibility and expeditious decision-making, it may also lead to certain inefficiencies in terms of longer distances traveled, duplication of routes, and increased fuel consumption.

The interview respondents mentioned that the application of advanced planning tools and optimization software, it could have a high impact on decision-making and eliminate operational inefficiencies. The integration and application of the mathematical algorithm such as linear programming and vehicle routing could help the company evaluate different routing scenarios and determine the most efficient transport plans.

### 4.2.4 Distribution Challenges and Operational Inefficiencies

The interviews also said that there are some distribution and operational challenges that affect current distribution system some of the challenges are

- Fluctuation of demand that made the transportation and the inventory scheduling difficult often require last minute adjustments to delivery plans.
- Traffic congestion in urban areas that leads to traffic delays increase delivery time and fuel consumption.
- Poor Road conditions in certain regional routes most of rural area also affect travel time and vehicle maintenance requirements which leads to high total cost.

- Vehicle availability was also mentioned as a potential constraint during peak demand periods (on hot weather condition.

These challenges shows that the current distribution needs more systematic and optimized approach on transportation planning that considers both operational constraints and efficiency objectives.

#### 4.2.5 Software and Planning Tool

The last theme that was covered in the interviews is the software and technology used for transportation planning and monitoring. According to the interviewees, the most used software for planning delivery schedules and order information is Microsoft Excel for information sharing NAV and telegram.

Although it can be used for basic planning, it does not have advanced features for optimization, unless it is used in conjunction with other software such as Solver. Currently, planning is done manually.

### 4.3 Quantitative Data Presentation

The quantitative data for this study were obtained from Moha Soft Drink S.C. internal distribution records, including:

- Supply capacity from Teklehaymanot and Dessie plants
- Demand from major distribution points
- Transportation costs between nodes
- Distance and route information

The data were structured into matrices suitable for:

- Transportation model
- Transshipment model
- Vehicle Routing Problem (VRP)

### 4.3.1 Selling price and transportation cost structure

The selling price and transportation cost data presented in table 4.1 and 4.2 were obtained through conducting an interview with personnel at moha soft drink industry. The table summarized the distribution cost structure for both Teklehaymanot and dessie plant .This information serve as an input for transportation and transshipment model developed on the next sections.

**Table 2Moha Soft Drink Teklehaymanot plant location of customers**

| urban Addis Ababa | | | | |
|---|---|---|---|---|
| Location | Distance (km) | Selling price per unit case | Transportation cost in birr | Total transportation fee |
| Winget | 10.4 | 4.16 | 0 | 4.16 |
| Ayer Tena | 3.2 | 4.16 | 0 | 4.16 |
| Merkato | 8.5 | 4.16 | 0 | 4.16 |
| Autobis Tera | 8.3 | 4.16 | 0 | 4.16 |
| Torhayiloch | 7.9 | 4.16 | 0 | 4.16 |

| inter-city / regional | | | | |
|---|---|---|---|---|
| Location | Distance (KM) | Selling price per unit case | Transportation Total cost | Add transportation fee |
| tulu bollo | 73.3 | 4.16 | 0 | 4.16 |
| Welikete | 14.6 | 4.16 | 0 | 4.16 |
| Sebeta | 16.6 | 4.16 | 0 | 4.16 |
| Furi | 10.2 | 4.16 | 0 | 4.16 |
| Holleta | 33.8 | 4.16 | 0 | 4.16 |
| Gedio | 404 | 4.16 | 0 | 4.16 |
| Guder | 125 | 4.16 | 0 | 4.16 |
| Shambo | 301 | 4.16 | 0.11 | 4.27 |

| | | | | |
|---|---|---|---|---|
| Bako | 273 | 4.16 | 0 | 4.16 |
| Enchine | 153 | 4.16 | 0 | 4.16 |
| werabe | 259 | 4.16 | 0 | 4.16 |
| Butajera | 220 | 4.16 | 0 | 4.16 |
| Nekemete | 219 | 4.16 | 0 | 4.16 |
| Gimbi | 425 | 4.16 | 0.11 | 4.27 |
| Nejo | 497 | 4.16 | 100 | 4.27 |
| Assosa | 660 | 4.16 | 100 | 4.27 |
| Gambella | 705 | 4.16 | 100 | 4.27 |
| Metu | 530 | 4.16 | 100 | 4.27 |
| Beadle | 420 | 4.16 | 100 | 4.27 |
| jimma | 394 | 4.16 | 100 | 4.27 |
| Asendabo | 296 | 4.16 | 0 | 4.16 |
| ashawa meda | 12.4 | 4.16 | 0 | 4.16 |

| **farther extensions** | | | | |
|---|---|---|---|---|
| Location | Distance (KM) | Selling price per unit case | Transportation cost in birr | Add transportation fee |
| Kobo | 187 | 3.97 | 0 | 3.97 |
| Weldiya | 86 | 3.97 | 0 | 3.97 |
| Bati | 100 | 3.97 | 0 | 3.97 |
| Ambassel | 60 | 3.97 | 0 | 3.97 |
| Debre Birhan | 161 | 3.97 | 0 | 3.97 |

| | | | | |
|---|---|---|---|---|
| Lalibela | 287 | 3.97 | 0 | 3.97 |

**Table 3Moha Soft Drink Dessie plant location of customers**

| **Closest to the plant** | | | | |
|---|---|---|---|---|
| Location | Distance (KM) | Selling price per unit case | Transportation cost in birr | Add transportation fee |
| Kombolcha | 24 | 3.97 | 0 | 3.97 |
| Hayq | 27 | 3.97 | 0 | 3.97 |
| Wuchale | 36 | 3.97 | 0 | 3.97 |
| Wurgessa | 60 | 3.97 | 0 | 3.97 |
| Were Ilu | 113 | 3.97 | 0 | 3.97 |
| Wogel Tena | 184 | 3.97 | 0 | 3.97 |
| Akesta | 101 | 3.97 | 0 | 3.97 |
| Degolo | 119 | 3.97 | 0 | 3.97 |

| Near to Addis Ababa and also to Dessie (possible indirect Dessie reach) | | | | |
|---|---|---|---|---|
| Location | Distance (KM) | Selling price per unit case | Transportation cost in birr | Add transportation fee S |
| Debre Birhan | 162 | 4.16 | 0 | 4.16 |
| Debre Sina | 267 | 4.16 | 0 | 4.16 |
| Ataye | 188 | 4.16 | 0 | 4.16 |
| Kemise | 75 | 4.16 | 0 | 4.16 |
| Shewa Robit | 178 | 4.16 | 0 | 4.16 |
| Tarmaber | 178 | 4.16 | 0 | 4.16 |
| Mehal Meda | 150 | 4.16 | 0 | 4.16 |
| Molale | 169 | 4.16 | 0 | 4.16 |
| Karakore | 200 | 4.16 | 0 | 4.16 |
| Sendafa | 115 | 4.16 | 0 | 4.16 |
| Chacha | 340 | 4.16 | 0.11 | 4.27 |
| Alem Ketema | 180 | 4.16 | 0 | 4.16 |
| Lemi | 180 | 4.16 | 0 | 4.16 |
| Gohatsion | 330 | 4.16 | 0.11 | 4.27 |

## 4.4 Transportation Model Formulation

The transportation problem is formulated as a linear programming model to determine the optimal shipment plan.

**Sets**

- $i \in I$: set of supply nodes ( Teklehaymanot and Desssie plants)
  in this case $I=\{1,2\} \rightarrow$ Teklehaymanot , Dessie
- $j \in J$: set of demand nodes (distribution locations)

**Decision Variable**

- Xij: quantity of products transported from plant i to destination j

**Constraints**

**a) Supply Constraints**

Each plant cannot ship more than its available supply:

$$\sum_{j \in J} Xij \leq Si \quad \forall i \in I$$

**b) Demand Constraints**

Each destination must receive its required demand:

$$\sum_{j \in J} Xij \leq Si \quad \forall j \in J$$

**Objective Function**

Minimize total transportation cost

$$\min Z = \sum_{i \in I} \sum_{j \in J} CijXij \leq Si \quad \forall j \in J$$

$$i,j \geq 0 \ \forall i \in I, j \in J$$

| TRANSPORTATION COST | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| factory | Winget | ayer tena | Merkato | autobis tera | Torhayiloch | tulu bollo | welikete | Sebeta | Furi | Holleta | Gedio | Guder | Shambo | Bako |
| teklehaymanot | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.27 | $4.16 |
| dessie | $13.50 | $13.80 | $13.20 | $13.00 | $13.70 | $14.50 | $13.40 | $14.20 | $14.00 | $14.80 | $13.60 | $15.50 | $13.30 | $4.50 |
| demand | 11900 | 55000 | 93100 | 42300 | 38100 | 33900 | 29600 | 27500 | 14800 | 19100 | 16900 | 16100 | 17800 | 12700 |
| sum of the unit cost | $17.66 | $17.96 | $17.36 | $17.16 | $17.86 | $18.66 | $17.56 | $18.36 | $18.16 | $18.96 | $17.76 | $19.66 | $17.57 | $8.66 |
| | $210,154.00 | $987,800.00 | $1,616,216.00 | $725,868.00 | $680,466.00 | $632,574.00 | $519,776.00 | $504,900.00 | $268,768.00 | $362,136.00 | $300,144.00 | $316,526.00 | $312,746.00 | $109,982.00 |
| Total transportation cost | 23,712,296 | | | | | | | | | | | | | |

| Enchine | werabe | Nekemete | Gimbi | Nejo | Assosa | Gambella | Metu | Beadle | jima | Asendabo | ashawa meda | Kobo | Weldiya | Bati |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $4.16 | $4.16 | $4.27 | $4.27 | $4.27 | $4.27 | $4.27 | $4.27 | $4.27 | $4.27 | $4.16 | $4.16 | $11.00 | $11.00 | $7.50 |
| $4.20 | $13.50 | $10.50 | $11.80 | $12.50 | $15.00 | $20.00 | $14.50 | $13.80 | $11.50 | $10.80 | $4.80 | $3.97 | $3.97 | $3.97 |
| 17800 | 27500 | 31800 | 25400 | 84700 | 21200 | 55000 | 38100 | 31800 | 27500 | 42300 | 23300 | 46600 | 33900 | 27500 |
| $8.36 | $17.66 | $14.77 | $16.07 | $16.77 | $19.27 | $24.27 | $18.77 | $18.07 | $15.77 | $14.96 | $8.96 | $14.97 | $14.97 | $11.47 |
| $148,808.00 | $485,650.00 | $469,686.00 | $408,178.00 | $1,420,419.00 | $408,524.00 | $1,334,850.00 | $715,137.00 | $574,626.00 | $433,675.00 | $632,808.00 | $208,768.00 | $697,602.00 | $507,483.00 | $315,425.00 |

| Ambassel | Lalibela | Kombolcha | Hayq | Wuchale | Wurgessa | Were Ilu | Wogel Tena | Akesta | Degolo | Debre Birhan | Debre Sina | Ataye | Kemise | Shewa Robit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $8.00 | $4.16 | $13.00 | $8.50 | $8.00 | $9.00 | $9.00 | $5.50 | $7.50 | $6.50 | $7.50 | $4.16 | $4.16 | $4.16 | $4.16 |
| $3.97 | $3.97 | $3.97 | $3.97 | $3.97 | $3.97 | $3.97 | $3.97 | $3.97 | $3.97 | $3.97 | $5.50 | $5.00 | $3.97 | $6.50 |
| 23300 | 29600 | 25400 | 33900 | 25400 | 29600 | 27500 | 25400 | 67700 | 23300 | 23300 | 21200 | 19100 | 19100 | 29600 |
| $11.97 | $8.13 | $16.97 | $12.47 | $11.97 | $12.97 | $12.97 | $9.47 | $11.47 | $10.47 | $11.47 | $9.66 | $9.16 | $8.13 | $10.66 |
| $278,901.00 | $240,648.00 | $431,038.00 | $422,733.00 | $304,038.00 | $383,912.00 | $356,675.00 | $240,538.00 | $776,519.00 | $243,951.00 | $267,251.00 | $204,792.00 | $174,956.00 | $155,283.00 | $315,536.00 |

| Tarmaber | Mehal Meda | Molale | Karakore | Sendafa | Chacha | Alem Ketema | Lemi | Gohatsion |
|---|---|---|---|---|---|---|---|---|
| $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.27 | $4.16 | $4.16 | $4.27 |
| $7.00 | $5.50 | $6.00 | $7.50 | $8.50 | $8.00 | $7.00 | $6.50 | $6.80 |
| 36000 | 46600 | 31800 | 25400 | 16100 | 20500 | 19700 | 21500 | 20800 |
| $11.16 | $9.66 | $10.16 | $11.66 | $12.66 | $12.27 | $11.16 | $10.66 | $11.07 |
| $401,760.00 | $450,156.00 | $323,088.00 | $296,164.00 | $203,826.00 | $251,535.00 | $219,852.00 | $229,190.00 | $230,256.00 |

**Figure 4 Total cost before using Transportation Model (linear programming)**

| Transportation cost per case (USD) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| factory | Winget | ayer tena | Merkato | autobis t | Torhayil och | tulu bollo | welikete | Sebeta | Furi | Holleta | Gedio | Guder | Shambo |
| teklehaymanot | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 | $4.27 |
| dessie | $13.50 | $13.80 | $13.20 | $13.00 | $13.70 | $14.50 | $13.40 | $14.20 | $14.00 | $14.80 | $13.60 | $15.50 | $13.30 |
| annual demand per case | 11900 | 55000 | 93100 | 42300 | 38100 | 33900 | 29600 | 27500 | 14800 | 19100 | 16900 | 16100 | 17800 |

| Bako | Enchine | werabe | Nekemte | Gimbi | Nejo | Assosa | Gambella | Metu | Bedle | jimma | Asendabo | ashawa meda | Kobo | Weldiya | Bati |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $4.16 | $4.16 | $4.16 | $4.27 | $4.27 | $4.27 | $4.27 | $4.27 | $4.27 | $4.27 | $4.27 | $4.16 | $4.16 | $11.00 | $11.00 | $7.50 |
| $4.50 | $4.20 | $13.50 | $10.50 | $11.80 | $12.50 | $15.00 | $20.00 | $14.50 | $13.80 | $11.50 | $10.80 | $4.80 | $3.97 | $3.97 | $3.97 |
| 12700 | 17800 | 27500 | 31800 | 25400 | 84700 | 21200 | 55000 | 38100 | 31800 | 27500 | 42300 | 23300 | 46600 | 33900 | 27500 |

| Ambassel | Debre Birhan | Lalibela | Kombolcha | Hayq | Wuchale | Wurgessa | Were Ilu | Wogel Tena | Akesta | Degolo | Debre Sina | Ataye | Kemise | Shewa Robit | Tarmaber |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $8.00 | $4.16 | $13.00 | $8.50 | $8.00 | $9.00 | $9.00 | $5.50 | $7.50 | $6.50 | $7.50 | $4.16 | $4.16 | $4.16 | $4.16 | $4.16 |
| $3.97 | $3.97 | $3.97 | $3.97 | $3.97 | $3.97 | $3.97 | $3.97 | $3.97 | $3.97 | $3.97 | $5.50 | $5.00 | $3.97 | $6.50 | $7.00 |
| 23300 | 29600 | 25400 | 33900 | 25400 | 29600 | 27500 | 25400 | 67700 | 23300 | 23300 | 21200 | 19100 | 19100 | 29600 | 36000 |

| Mehal Meda | Molale | Karakore | Sendafa | Chacha | Alem Ketema | Lemi | Gohatsion | capacity |
|---|---|---|---|---|---|---|---|---|
| $4.16 | $4.16 | $4.16 | $4.16 | $4.27 | $4.16 | $4.16 | $4.27 | 650000 |
| $5.50 | $6.00 | $7.50 | $8.50 | $8.00 | $7.00 | $6.50 | $6.80 | 400000 |
| 46600 | 31800 | 25400 | 16100 | 20500 | 19700 | 21500 | 20800 | |

**Figure 5 annual transportation and demand of Tekelehaymanot plant**

**Source :Excel output**

**Total cost after using transportation model (linear programming)**

| factory | Winget | ayer tena | Merkato | autobis t | Torhayiloch | tulu bollo | welikete | Sebeta | Furi | Holleta | Gedio | Guder | Shambo | Bako |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| teklehaymanot | 11900 | 55000 | 93100 | 42300 | 38100 | 33900 | 29600 | 27500 | 14800 | 19100 | 16900 | 16100 | 0 | 12700 |
| dessie | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 11900 | 55000 | 93100 | 42300 | 38100 | 33900 | 29600 | 27500 | 14800 | 19100 | 16900 | 16100 | 0 | 12700 |
| annual demand | 11900 | 55000 | 93100 | 42300 | 38100 | 33900 | 29600 | 27500 | 14800 | 19100 | 16900 | 16100 | 17800 | 12700 |
| | | | | | | | | | | | | | | |
| TOTAL COST | 4292000 | | | | | | | | | | | | | |

| Enchine | werabe | Nekemete | Gimbi | Nejo | Assosa | Gambella | Metu | Bedle | jimma | Asendabo | ashawa meda | Kobo | Weldiya | Bati |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17800 | 27500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42300 | 23300 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 46600 | 33900 | 27500 |
| 17800 | 27500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42300 | 23300 | 46600 | 33900 | 27500 |
| 17800 | 27500 | 31800 | 25400 | 84700 | 21200 | 55000 | 38100 | 31800 | 27500 | 42300 | 23300 | 46600 | 33900 | 27500 |

| Ambassel | Debre Birhan | Lalibela | Kombolcha | Hayq | Wuchale | Wurgessa | Were Ilu | Wogel Tena | Akesta | Degolo | Debre Sina | Ataye | Kemise | Shewa Robit | Tarmaber |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 29,600 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21,200 | 19,100 | 19,100 | 29,600 | 9,500 |
| 23300 | 0 | 25400 | 33900 | 25400 | 29600 | 27500 | 25400 | 67700 | 23300 | 10500 | 0 | 0 | 0 | 0 | 0 |
| 23300 | 29600 | 25400 | 33900 | 25400 | 29600 | 27500 | 25400 | 67700 | 23300 | 10500 | 21200 | 19100 | 19100 | 29600 | 9500 |
| 23300 | 29600 | 25400 | 33900 | 25400 | 29600 | 27500 | 25400 | 67700 | 23300 | 23300 | 21200 | 19100 | 19100 | 29600 | 36000 |

| Mehal Meda | Molale | Karakore | Sendafa | Chacha | Alem Ketema | Lemi | Gohatsion | | capacity |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 650000 | 650000 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 400000 | 400000 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| 46600 | 31800 | 25400 | 16100 | 20500 | 19700 | 21500 | 20800 | | |

**Figure 6 Total cost after using transportation model (linear programming)**

**Source : Excel solver output**

**Summary of the Transportation model**

The transportation model was solved using excel solver by minimizing total transportation cost subject to supply and demand constraint .The initial cost before optimization was 23,712,296 ,after applying linear programming ,the total cost was reduced to 4,292,000.This represent a significant cost minimization achieved through optimal allocation of products from the two plants to respective destination .over all ,the results confirm that linear programming is an effective for improving distribution efficiency and minimizing operational costs.

This reduction shows that employing optimization strategies results in a more effective distribution of shipments between the Teklehaymanot and Dessie factories and their corresponding distribution locations. Eliminating ineffective shipment patterns, cutting back on long distance deliveries, and making greater use of available supply capacities are how the improvement is accomplished.

The results are in line with Agadaga's (2019) study, which shown that by reducing costs and maximizing flow allocation, transportation models greatly increase distribution efficiency in beverage businesses.

In addition to that the results show that the company currently uses manual planning approach that does not fully take advantage of cost saving opportunities. According to (Hergart, 2022) ,

conventional transportation systems that depend on experience based decision-making frequently result in higher operating costs and inefficiencies, especially in extensive distribution networks.

This show that, as compared to manual planning techniques, mathematical optimization models can significantly increase distribution efficiency. In addition to lowering operating expenses, the optimized transportation strategy improves resource efficiency and transportation coordination throughout the distribution network.

In terms of sustainability, the optimization model supports more environmentally friendly transportation operations by reducing unnecessary travel distances and minimizing inefficient shipment movements. Fuel consumption drops as cars use shorter, more efficient routes, which immediately reduces air pollution and greenhouse gas emissions. Better shipment distribution also helps the business make more responsible use of its transportation resources by lowering vehicle under-utilization and longer trips. As a result, the use of transportation optimization promotes environmental sustainability and more sustainable logistics operations in addition to enhancing economic performance through cost reduction.

## 4.5 Cluster Based Center of Gravity

The location were grouped based on geographical clustering which is based on road network accessibility and proximity to the plant (Teklehaymnaot and Dessie ).geographical clustering is selected because the objective is to facility location analysis then finding center of gravity rather than cluster optimization.

**Cluster of Teklehaymanot plant**

**Table 4 Cluster 1:Addis Ababa metropolitan area**

| location | x axis | y axis | demand |
|---|---|---|---|
| Winget | 9.05674499 | 38.7139816 | 11900 |
| ayer tena | 8.98363789 | 38.7071585 | 55000 |
| Merkato | 9.03075128 | 38.7388111 | 93100 |
| autobis tera | 9.03075128 | 38.7344713 | 42300 |
| Torhayiloch | 9.01334823 | 38.7542088 | 38100 |
| ashawa meda | 9.02981226 | 38.6603405 | 23300 |
| Sebeta | 8.91250553 | 38.6239335 | 27500 |
| Furi | 8.93678493 | 38.6763796 | 14800 |
| Holleta | 9.06980451 | 38.4966085 | 19100 |

| | | | |
|---|---|---|---|
| ceneter of gravity | 9.00963965 | 38.7013739 | near to ambo |

**Table 5 Cluster 2: South west corridor**

| Location | x axis | y axis | demand |
|---|---|---|---|
| Werabe | 7.85317784 | 38.1864861 | 27500 |
| tulu bollo | 8.66123567 | 38.2134748 | 33900 |
| Asendabo | 7.76606059 | 37.2319364 | 42300 |
| Jimma | 7.85844947 | 36.5795801 | 27500 |
| ceneter of gravity | 8.03498478 | 37.5488912 | Near to sokoru |

**Table 6Cluster 3: western shewa corridor**

| Location | x axis | y axis | demand |
|---|---|---|---|
| Guder | 8.97030718 | 37.7601599 | 16100 |
| Enchine | 8.81807498 | 37.6587896 | 17800 |
| Welikete | 8.2923543 | 37.781553 | 29600 |
| Bako | 9.12527485 | 37.0576572 | 12700 |
| Shambo | 9.56714987 | 37.0991562 | 17800 |
| center of gravity | 8.86195346 | 37.5276194 | Tikur enchine |

**Table 7Cluster 4: western Ethiopia corridor**

| location | x axis | y axis | demand |
|---|---|---|---|
| Nekemete | 9.10107688 | 36.534132 | 31800 |
| Beadle | 8.46480624 | 36.3492534 | 31800 |
| Metu | 8.29755607 | 35.5818582 | 38100 |
| Nejo | 9.50743381 | 35.5002164 | 84700 |
| Assosa | 10.065078 | 34.5408008 | 21200 |
| Gambella | 8.25268786 | 34.5882222 | 55000 |
| Gedio | 6.1997229 | 38.2528942 | 16900 |
| Gimbi | 9.1877014 | 35.8270665 | 25400 |
| ceneter of gravity | 8.80758292 | 35.6553866 | magaala dabasoo ,west wellega |

**Cluster of Dessie plant**

**Table 8 Cluster 1:Addis north shewa corridor**

| location | x axis | y axis | demand |
|---|---|---|---|
| Debre Birhan | 9.671236787 | 39.52958083 | 29600 |
| Debre Sina | 9.849465458 | 39.87610021 | 21200 |
| Alem Ketema | 10.06062314 | 38.98592652 | 19700 |
| Lemi | 9.803423203 | 38.90790932 | 21500 |
| Gohatsion | 10.00710972 | 38.2496695 | 20800 |
| ceneter of gravity | 9.859867318 | 39.14525572 | Enewari ,North shewa |

**Table 9 Cluster 2:Ataye kemise corridor**

| location | x axis | y axis | demand |
|---|---|---|---|
| Ataye | 10.34273074 | 39.95777977 | 19100 |
| Kemise | 10.72441015 | 39.8676805 | 19100 |
| Shewa Robit | 10.72441015 | 39.89727966 | 29600 |
| Karakore | 10.42359751 | 39.93310313 | 25400 |
| Mehal Meda | 10.30933074 | 39.6527718 | 46600 |
| tarma ber | 10.16523034 | 39.5000761 | 36000 |
| center of gravity | 10.41494547 | 39.75966151 | near to majete (north shewa ) |

**Table 10 Cluster 3:south wello corridor**

| location | x axis | y axis | demand |
|---|---|---|---|
| Kombolcha | 11.08609978 | 39.72356799 | 33900 |
| Hayq | 11.31218908 | 39.67926969 | 25400 |
| Wuchale | 11.51294633 | 39.6102803 | 29600 |
| Wurgessa | 11.54363794 | 39.62167765 | 27500 |
| Were Ilu | 10.59398461 | 39.43497393 | 25400 |
| Akesta | 10.87686491 | 39.16988596 | 23300 |
| Degolo | 10.42514087 | 39.25421562 | 23300 |
| Bati | 11.18866002 | 40.03711261 | 27500 |
| center of gravity | 11.09075375 | 39.58542538 | near to dessie |

**Table 11 Cluster 4: North wello corridor**

| location | x axis | y axis | demand |
|---|---|---|---|
| Kobo | 12.1099694 | 39.4187166 | 46600 |
| Weldiya | 11.8303466 | 39.59743 | 33900 |

| | | | |
|---|---|---|---|
| Lalibela | 12.0359625 | 39.0431571 | 25400 |
| Ambassel | 11.7542355 | 39.2405599 | 23300 |
| Wogel Tena | 11.593933 | 39.20969 | 67700 |
| **center of gravity** | 11.8327564 | 39.3080869 | Guba E' Mengeriya (north wollo zone ) |

### 4.6 Transshipment Model Results

The transshipment model was developed using excel solver to represent the distribution network, including source, intermediate nodes, and final destinations. The objective of the model is to minimize total transportation cost while satisfying capacity and demand. Excel solver was then used to determine the optimal shipment plan.

**Sets**

i,j∈N, set of all nodes in the network

Where:

- Supply nodes (Teklehaymanot and Dessie plants)
- Transshipment nodes (intermediate distribution points)
- Demand nodes (final destinations)

**Decision Variable**

Xij: quantity transported from node i to node j

**Constraints**

1. Flow Conservation Constraints

For every node:

$$\sum_{i \in I} Xij \; - \sum_{j \in J} Xij \; - bi \qquad \forall i \in N$$

**Objective Function**

Minimize total transportation cost across the network

$\min Z = \sum_{i \in N} \sum_{j \in N} CijXij$

$X_{ij} \geq 0 \forall i,j$

| | Tikur enchine | near to ambo | near to sokoru | Magaala dabasoo | shipped | capacity | | |
|---|---|---|---|---|---|---|---|---|
| Teklehaymanot | 0 | 0 | 0 | 0 | 0 | 650000 | | |
| shipped | 42831 | 0 | 0 | 0 | | | | |

| Distribution center | guder | enchine | welikete | bako | shambo | Winget | ayer tena | merkato | a |
|---|---|---|---|---|---|---|---|---|---|
| Tikur enchine | 1234 | 1548 | 1547 | 1478 | 1478 | 1456 | 1358 | 1548 | |
| near to ambo | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| near to sokoru | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| Magaala dabasoo | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| demand | 1234 | 1548 | 1547 | 1478 | 1478 | 1456 | 1358 | 1548 | |
| shipped | 1234 | 1548 | 1547 | 1478 | 1478 | 1456 | 1358 | 1548 | |

| | | |
|---|---|---|
| transshipment | Tikur enchine | 0 |
| | near to ambo | 0 |
| | near to sokoru | 0 |
| | Magaala dabasoo | 0 |
| cost | 289061.65 | |

**Figure 7Transshipment depot and annual shipping cost of teklehaymanot plant**

| | Enewari | near to majete | near to dessie | Guba E' Mengeriya | shipped | capacity | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dessie | 0 | 0 | 38480 | 0 | 38480 | 400000 | | | | | | |
| shipped | 0 | 0 | 38480 | 0 | | | | | | | | |

| Distribution center | Debre Birhan | Debre Sina | Alem Ketema | Lemi | Gohatsion | Ataye | Kemise | Shewa Rol | Karakore | Mehal Me | tarma ber | Kombolch |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Enewari | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| near to majete | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| near to dessie | 1478 | 1456 | 1358 | 1548 | 1365 | 1547 | 3214 | 1234 | 1548 | 1547 | 1478 | 1478 |
| Guba E' Mengeriya | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| demand | 1478 | 1456 | 1358 | 1548 | 1365 | 1547 | 3214 | 1234 | 1548 | 1547 | 1478 | 1478 |
| shipped | 1478 | 1456 | 1358 | 1548 | 1365 | 1547 | 3214 | 1234 | 1548 | 1547 | 1478 | 1478 |

| | | |
|---|---|---|
| transshipment | Enewari | 0 |
| | near to majete | 0 |
| | near to dessie | 0 |
| | Guba E' Mengeriya | 0 |
| | cost | 334807.5 |

**Figure 8Transshipment depot and annual shipping cost of Dessie plant**

**source : Excel solver output**

**Summary of the Transshipment model**

The transshipment model was solved using excel solver ,resulting in an optimal distribution plan that minimize total transportation cost across the network .The total cost obtained from the optimization solution from both Teklehaymanot and Dessie plant 623,868.70.This result shows that most efficient routing of products from the plants through intermediate transshipment points to the final destination while satisfying all supply chain and demand .over all the result confirms that the transshipment approach is effective in reducing transportation cost .

The transshipment approach supports the company to better coordinate deliveries between the Teklehaymanot and Dessie plants and the final market destinations. Goods might be moved through carefully placed intermediate sites rather than being transported directly to every destination, which would increase truck utilization and decrease the number of repetitive trips. As a result, the transportation network's overall performance was enhanced and fuel consumption and operational inefficiencies were reduced.

In comparison to the current manual distribution method, the transshipment model offered a more adaptable and economical distribution strategy. The outcome highlights how crucial it is to incorporate transshipment choices into transportation planning in beverage distribution networks.

From a sustainability standpoint, the transshipment model reduces the impact on the environment by reducing the number of unnecessary vehicle movements and enhancing load consolidation throughout the network. Vehicle capacity utilization can be increased through improved coordination between plants and intermediate distribution sites, which lowers fuel loss and transportation inefficiencies. As a result, the business can enhance overall energy efficiency within the distribution system, cut carbon emissions. As a result, putting transshipment optimization into practice helps create a more sustainable transportation network in addition to improving operations and finances.

The results are also consistent with (Hergart, 2022) discussion of sustainable transportation ideas because the improved network enhances vehicle utilization and reduces overall trip

distance. This results in decreased emissions, less fuel use, and better environmental performance all around.

### 4.6 Vehicle Routing Model Results

The Vehicle Routing Problem (VRP) was developed to find the most effective delivery routes for Moha Soft Drink Teklehaymanot and Dessie plant .it is delivering goods to various client locations while reducing operational costs and transportation distance. In contrast to the transportation and transshipment models, the VRP concentrates on vehicle assignment and route sequencing.

The distribution network, client demand locations, vehicle capabilities, and node to node travel distances are all taken into account by the model. Finding the best delivery routes that satisfy operational limitations while lowering overall trip distance, fuel consumption, and delivery time is the goal.

Microsoft Excel and Google map was use d to solve the VRP. The best routing configuration for the available vehicles was produced by the solution using distance data between delivery locations as inputs for route optimization. We applied Clarke and Wright algorithm .The distance matrix identifies the distance between every pair of locations to be visited. If the transportation costs between every pair of locations are known, the cost can be used in place of distance. The distance dij on a grid between points i with a coordinates (xi, yi) and a point j with a coordinate (xj, yj) is evaluated as:

$$\mathbf{d_{ij}}=\sqrt{(\boldsymbol{xi}-\boldsymbol{xj})^2}+(\boldsymbol{yi}-\boldsymbol{yi})^2$$

where: d$n$ = Distance

x= Latitude or lines of latitude on Earth

y= Longitude or the Earth's meridian

After calculating the estimated distance proceed to finding the saving distance using the formula $\mathbf{Sij = C0i + C0j - Cij}$

Then after Sort the savings in decreasing order finally take edge [i,j] from the top of the savings list. Join two separate cycles with edge [i,j], if

- The nodes belong to separate cycles
- The maximum capacity of the vehicle is not exceeded.
- i and j are first or last customer on their cycles and Repeat 4 until the savings list is handled or the capacities don't allow more.

**Parameters**=number of points (1-depot,2-depot ,……n-clients)

**$D_{ij}$**=distance from point I to point j

**$D_i$**=demand from client I

**C**=capacity of each truck

Variables $X_{ij}$=1 if a truck goes from node i to node j

$F_{ij}$=the number of unit in the truck going from node i to node j

$\min \sum_{i=1}^{n} \sum_{j=1}^{n} dijxij$

$\sum_{j=1}^{n} xij = 1 \quad \forall \mathrm{i} = 2,..,\mathrm{n}$

$\sum_{j=1}^{n} xji = 1 \quad \forall \mathrm{i} = 2,..,\mathrm{n}$

$\sum_{j=1}^{n} fji - \sum_{j=1}^{n} fij = Di \quad \forall \mathrm{i} = 2,..,\mathrm{n}$

$0 \leq fji \leq \mathrm{Cij} \quad \forall \mathrm{i,j} = 1,\ldots,\mathrm{n}$

$xij \in (0,1) \forall i,j = 1,\ldots,n$

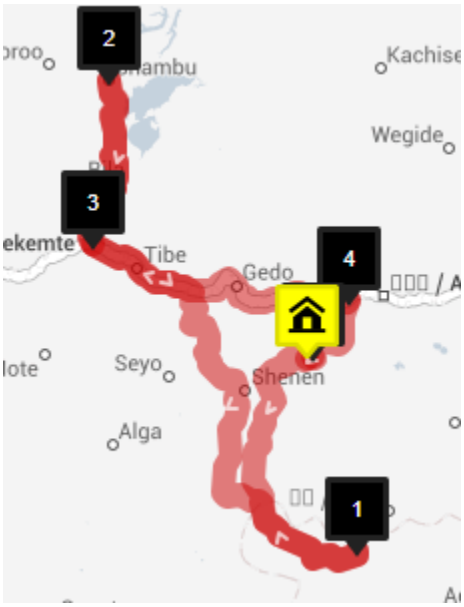
| | daily demand |
|---|---|
| guder | 44 |
| enchine | 49 |
| welikete | 81 |
| bako | 35 |
| shambo | 49 |
| capacity | 625 |

| | | | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| | estimated distance | Tikur enchine | guder | enchine | welikete | bako | shambo |
| | Tikur enchine | 0 | 0.236471 | 0.096571 | 0.58675 | 0.582623 | 0.865357 |
| 1 | guder | | 0 | 0.182895 | 0.67829 | 0.719392 | 0.890588 |
| 2 | enchine | | | 0 | 0.539874 | 0.675039 | 0.935015 |
| 3 | welikete | | | | 0 | 1.10353 | 1.445948 |
| 4 | bako | | | | | 0 | 0.443819 |
| 5 | shambo | | | | | | 0 |

| savings | |
|---|---|
| s12 | 0.150147 |
| s13 | 0.144931 |
| s14 | 0.099702 |
| s15 | 0.211241 |
| s23 | 0.00503 |
| s24 | 0.004154 |
| s25 | 0.026913 |
| s34 | 0.348577 |
| s35 | 0.006159 |
| s45 | 1.00416 |

| order | |
|---|---|
| s45 | 1.00416 |
| s34 | 0.348577 |
| s15 | 0.211241 |
| s12 | 0.150147 |
| s13 | 0.144931 |
| s14 | 0.099702 |
| s25 | 0.026913 |
| s35 | 0.006159 |
| s23 | 0.00503 |
| s24 | 0.004154 |

**Source :Excel output**




Source : RouteXL: fastest route with multiple stops (online software )

**Figure 9 vehicle routing optimization starting from tikure enchini ( a)capacity and demand analysis ;(b) clarke and wright savings algorithm matrix ; (c) final optimized delivery route map**

| | daily demand |
|---|---|
| Winget | 33 |
| ayer tena | 151 |
| merkato | 255 |
| autobis tera | 116 |
| torhayiloch | 104 |
| ashawa meda | 64 |
| sebeta | 75 |
| furi | 41 |
| holleta | 52 |
| capacity | 300 |

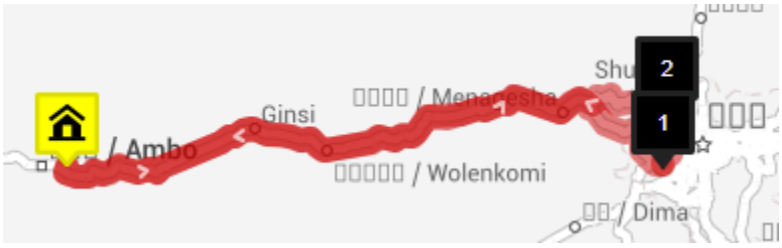
| | x axzi | y axis | demand |
|---|---|---|---|
| Winqet | 9.056745 | 38.71398 | 11900 |
| ayertona | 8.983638 | 38.70716 | 55000 |
| merkata | 9.030751 | 38.73881 | 93100 |
| autabir tora | 9.030751 | 38.73447 | 42300 |
| tarhayila ch | 9.013348 | 38.75421 | 38100 |
| arhawa meda | 9.029812 | 38.66034 | 23300 |
| zobota | 8.912506 | 38.62393 | 27500 |
| furi | 8.936785 | 38.67638 | 14800 |
| halleta | 9.069805 | 38.49661 | 13100 |
| conter c | 9.0057 | 38.683 | near to ambo |

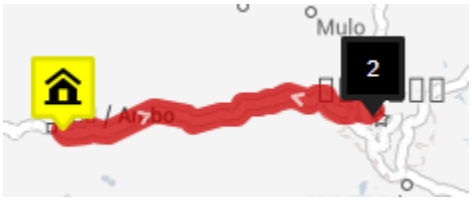
| estimated distance | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| | ambo | Winqet | ayertona | merkata | autabir tora | tarhayila ch | arhawa meda | zobota | furi | halleta |
| ambo | 0 | 0.057 | 0.0283 | 0.0561 | 0.0522 | 0.066 | 0.0371 | 0.1135 | 0.07 | 0.2024 |
| 1 Winqet | | 0 | 0.0734 | 0.0359 | 0.0331 | 0.0592 | 0.06 | 0.17 | 0.1257 | 0.2178 |
| 2 ayertona | | | 0 | 0.0545 | 0.0556 | 0.0556 | 0.0658 | 0.1095 | 0.0561 | 0.2275 |
| 3 merkata | | | | 0 | 0.0043 | 0.0232 | 0.0785 | 0.1643 | 0.1128 | 0.2453 |
| 4 autabir tora | | | | | 0 | 0.0263 | 0.0003 | 0.1613 | 0.1105 | 0.241 |
| 5 tarhayila ch | | | | | | 0 | 0.0741 | 0.1647 | 0.1092 | 0.2637 |
| 6 arhawa meda | | | | | | | 0 | 0.0944 | 0.0944 | 0.1685 |
| 7 zobota | | | | | | | | 0 | 0.0578 | 0.2024 |
| 8 furi | | | | | | | | | 0 | 0.133 |
| 9 halleta | | | | | | | | | | 0 |

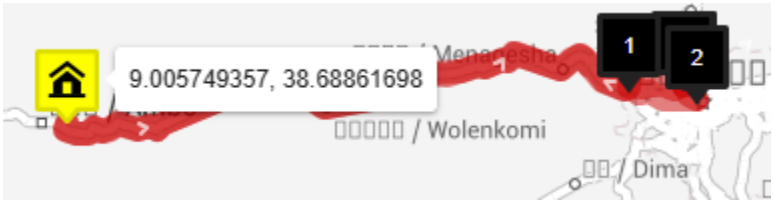
| | |
|---|---|
| z12 | 0.0124 |
| z13 | 0.0771 |
| z14 | 0.0761 |
| z15 | 0.0638 |
| z16 | 0.0004 |
| z17 | 0.0004 |
| z18 | 0.0013 |
| z19 | 0.0416 |
| z23 | 0.0305 |
| z24 | 0.0254 |
| z25 | 0.0002 |
| z26 | 0.0329 |
| z27 | 0.0329 |
| z28 | 0.0428 |
| z29 | 0.0038 |
| z34 | 0.1139 |
| z33 | 0.0889 |
| z35 | 0.0389 |
| z36 | 0.0147 |
| z37 | 0.0047 |
| z38 | 0.0133 |
| z39 | 0.0132 |
| z45 | 0.0919 |
| z46 | 0.0884 |
| z47 | 0.0038 |
| z48 | 0.0118 |
| z43 | 0.0136 |
| z56 | 0.029 |
| z57 | 0.0148 |
| z58 | 0.0269 |
| z53 | 0.0047 |
| z67 | 0.0562 |
| z68 | 0.0128 |
| z69 | 0.071 |
| z78 | 0.1257 |
| z79 | 0.1135 |
| z89 | 0.1394 |

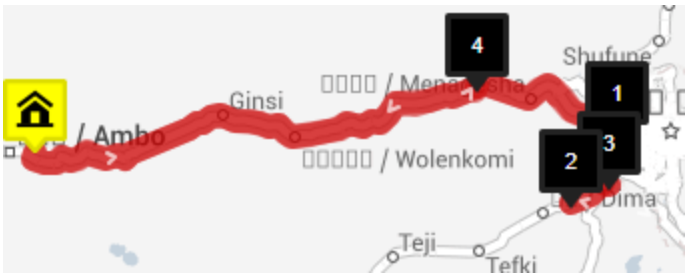
| order | |
|---|---|
| z89 | 0.1394 |
| z78 | 0.1257 |
| z34 | 0.1139 |
| z79 | 0.1135 |
| z35 | 0.0389 |
| z45 | 0.0919 |
| z33 | 0.0889 |
| z46 | 0.0884 |
| z13 | 0.0771 |
| z14 | 0.0761 |
| z69 | 0.071 |
| z15 | 0.0638 |
| z67 | 0.0562 |
| z28 | 0.0428 |
| z19 | 0.0416 |
| z27 | 0.0329 |
| z26 | 0.0329 |
| z23 | 0.0305 |
| z56 | 0.029 |
| z58 | 0.0269 |
| z24 | 0.0254 |
| z57 | 0.0148 |
| z36 | 0.0147 |
| z43 | 0.0136 |
| z38 | 0.0133 |
| z39 | 0.0132 |
| z68 | 0.0128 |
| z12 | 0.0124 |
| z48 | 0.0118 |
| z59 | 0.0047 |
| z37 | 0.0047 |
| z29 | 0.0038 |
| z47 | 0.0038 |
| z18 | 0.0013 |
| z16 | 0.0004 |
| z17 | 0.0004 |
| z25 | 0.0002 |

**Source :Excel output**






Source : RouteXL: fastest route with multiple stops (online software )

**Figure 10 vehicle routing optimization starting from ambo ( a)capacity and demand analysis ;(b) Clarke and wright savings algorithm matrix ; (c) final optimized delivery route map**

| | daily demand |
|---|---|
| werabe | 75 |
| tulu bollo | 93 |
| asendabo | 116 |
| jimma | 75 |
| capacity | 1000 |

| | | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|
| | estimated distance | sokoru | werabe | tulu bollo | asendabo | jimma |
| | sokoru | 0 | 0.663009 | 0.672773 | 1.121617 | 1.388394 |
| 1 | werabe | | 0 | 0.808508 | 0.958517 | 1.606915 |
| 2 | tulu bollo | | | 0 | 1.135297 | 1.444118 |
| 3 | asendabo | | | | 0 | 1.277891 |
| 4 | jimma | | | | | 0 |

| savings | |
|---|---|
| s12 | 0.527273 |
| s13 | 0.82611 |
| s14 | 0.444488 |
| s23 | 0.835873 |
| s24 | 0.617048 |
| s34 | 1.121617 |

| order | |
|---|---|
| s14 | 0.444488 |
| s12 | 0.527273 |
| s24 | 0.617048 |
| s13 | 0.82611 |
| s23 | 0.835873 |
| s34 | 1.121617 |

**Source :Excel output**




Source : RouteXL: fastest route with multiple stops (online software )

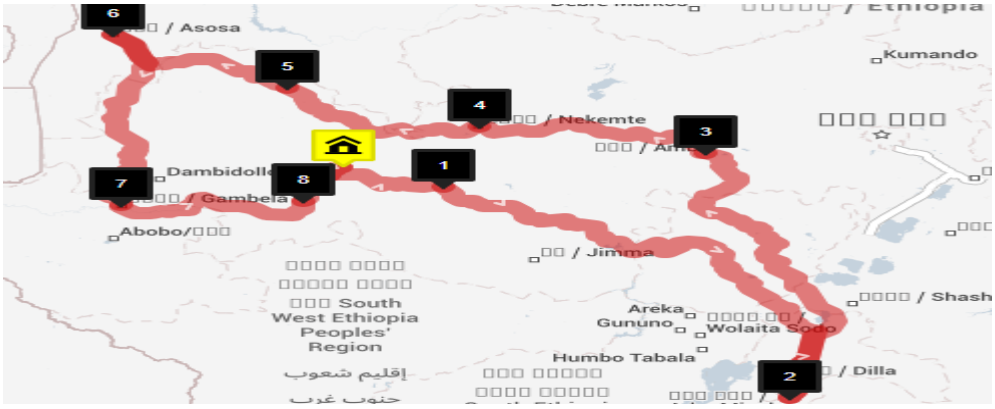
| | daily demand |
|---|---|
| nekemete | 33 |
| bedele | 151 |
| metu | 255 |
| nejo | 116 |
| assosa | 104 |
| gambella | 64 |
| gedio | 75 |
| gimbi | 41 |
| capacity | 2000 |

| | estimated distance | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | magaala dabasoo | e | bedele | metu | nejo | assosa | gambella | gedio | gimbi |
| | magaala dabasoo | 0 | 0.8527 | 0.574 | 0.4226 | 0.9064 | 1.8957 | 1.284 | 3.465 | 0.5333 |
| 1 | nekemete | | 0 | 0.6626 | 1.246 | 1.1109 | 2.2142 | 2.1228 | 3.3722 | 0.7124 |
| 2 | bedele | | | 0 | 0.7854 | 1.3446 | 2.4148 | 1.7738 | 2.9588 | 0.8918 |
| 3 | metu | | | | 0 | 1.2126 | 2.0513 | 0.9946 | 3.3964 | 0.9233 |
| 4 | nejo | | | | | 0 | 1.1097 | 1.2547 | 4.3033 | 0.4572 |
| 5 | assosa | | | | | | 0 | 1.5512 | 5.3592 | 1.557 |
| 6 | gambella | | | | | | | 0 | 1.5521 | 1.5521 |
| 7 | gedio | | | | | | | | 0 | 3.8487 |
| 8 | gimbi | | | | | | | | | 0 |

| savings | |
|---|---|
| s12 | 0.764 |
| s13 | 0.0292 |
| s14 | 0.6482 |
| s15 | 0.5342 |
| s16 | 0.9455 |
| s17 | 0.9455 |
| s18 | 0.6736 |
| s23 | 0.2111 |
| s24 | 0.1358 |
| s25 | 0.0842 |
| s26 | 1.0802 |
| s27 | 1.0802 |
| s28 | 0.2155 |
| s34 | 1.5895 |
| s35 | 0.267 |
| s36 | 0.7119 |
| s37 | 0.4912 |
| s38 | 0.0326 |
| s45 | 1.6924 |
| s46 | 0.9356 |
| s47 | 0.0682 |
| s48 | 0.9825 |
| s56 | 1.6286 |
| s57 | 0.0016 |
| s58 | 0.872 |
| s67 | 3.1969 |
| s68 | 0.2652 |
| s78 | 0.1496 |

| order | |
|---|---|
| s67 | 3.1969 |
| s45 | 1.6924 |
| s56 | 1.6286 |
| s34 | 1.5895 |
| s27 | 1.0802 |
| s26 | 1.0802 |
| s48 | 0.9825 |
| s46 | 0.9455 |
| s16 | 0.9455 |
| s46 | 0.9356 |
| s58 | 0.872 |
| s12 | 0.764 |
| s36 | 0.7119 |
| s18 | 0.6736 |
| s16 | 0.6482 |
| s15 | 0.5342 |
| s37 | 0.4912 |
| s35 | 0.267 |
| s68 | 0.2652 |
| s28 | 0.2155 |
| s23 | 0.2111 |
| s57 | 0.1496 |
| s24 | 0.1358 |
| s25 | 0.0842 |
| s47 | 0.0682 |
| s38 | 0.0326 |
| s13 | 0.0292 |
| s57 | 0.0016 |

**Source :Excel output**



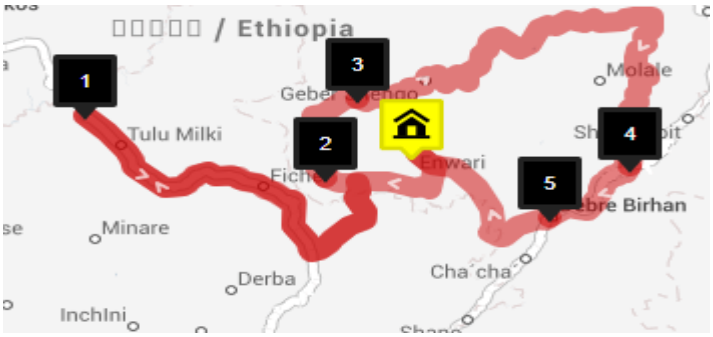

Source : RouteXL: fastest route with multiple stops (online software )

**Figure 11 vehicle routing optimization starting from megaala dabasso ( a)capacity and demand analysis ;(b) Clarke and wright savings algorithm matrix ; (c) final optimized delivery route map**

| | daily demand |
|---|---|
| Debre Birha | 81 |
| Debre Sina | 49 |
| Alem Ketem | 81 |
| Lemi | 35 |
| Gohatsion | 49 |
| capacity | 625 |

| | | | 1 | 2 | 3 | 4 | 5 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | estimate | Enewari | Debre Birhan | Debre Sir | Alem Kete | Lemi | Gohatsion | savings | | order | |
| | Enewari | 0 | 0.428120621 | 2.523777 | 1.875586 | 1.654982 | 1.355828 | s12 | 2.562229 | s23 | 3.730647 |
| 1 | Debre Birhan | | 0 | 0.389668 | 0.668716 | 0.63557 | 1.323247 | s13 | 1.63499 | s24 | 2.587745 |
| 2 | Debre Sina | | | 0 | 1.818058 | 1.591013 | 1.327778 | s14 | 1.447533 | s12 | 2.562229 |
| 3 | Alem Ketema | | | | 0 | 1.884679 | 1.777505 | s15 | 0.460701 | s25 | 2.551826 |
| 4 | Lemi | | | | | 0 | 0.689034 | s23 | 3.730647 | s45 | 2.321776 |
| 5 | Gohatsion | | | | | | 0 | s24 | 2.587745 | s13 | 1.63499 |
| | | | | | | | | s25 | 2.551826 | s35 | 1.453909 |
| | | | | | | | | s34 | 1.346735 | s14 | 1.447533 |
| | | | | | | | | s35 | 1.453909 | s34 | 1.346735 |
| | | | | | | | | s45 | 2.321776 | s15 | 0.460701 |

**Source :Excel output**




Source : RouteXL: fastest route with multiple stops (online software )

**Figure 12 vehicle routing optimization starting from enewari ( a)capacity and demand analysis ;(b) Clarke and wright savings algorithm matrix ; (c) final optimized delivery route map**

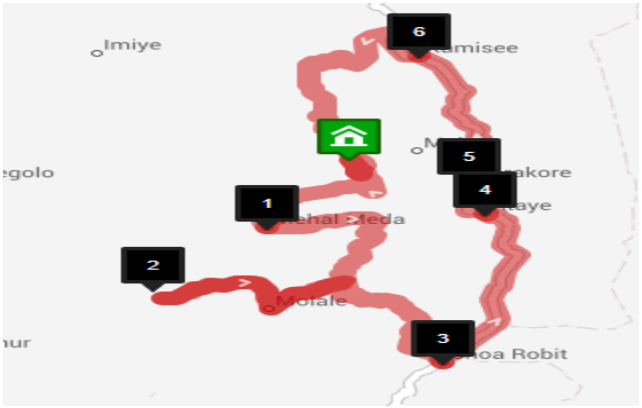
| | daily demand |
|---|---|
| Ataye | 52 |
| Kemise | 52 |
| Shewa Ro | 81 |
| Karakore | 70 |
| Mehal Me | 128 |
| tarma ber | 99 |
| capacity | 525 |

| | estimated distance | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|---|
| | | majete | Ataye | Kemise | Shewa Rc | Karakore | Mehal Meda | tarma ber |
| | majete | 0 | 0.226305 | 0.272544 | 0.284445 | 0.169031 | 0.199008924 | 0.407285 |
| 1 | Ataye | | 0 | 0.39217 | 0.386445 | 0.084548 | 0.306831259 | 0.490917 |
| 2 | Kemise | | | 0 | 0.029599 | 0.307845 | 0.467414876 | 0.66919 |
| 3 | Shewa Robit | | | | 0 | 0.302938 | 0.481741643 | 0.685896 |
| 4 | Karakore | | | | | 0 | 0.302725204 | 0.258367 |
| 5 | Mehal Meda | | | | | | 0 | 0.504248 |
| 6 | tarma ber | | | | | | | 0 |

| savings | |
|---|---|
| s12 | 0.106679 |
| s13 | 0.124305 |
| s14 | 0.310788 |
| s15 | 0.118483 |
| s16 | 0.226305 |
| s23 | 0.52739 |
| s24 | 0.13373 |
| s25 | 0.010639 |
| s26 | 0.272544 |
| s34 | 0.065102 |
| s35 | 0.001712 |
| s36 | 0.005834 |
| s45 | 0.065315 |
| s46 | 0.317949 |
| s56 | 0.102046 |

| order | |
|---|---|
| s23 | 0.52739 |
| s46 | 0.317949 |
| s14 | 0.310788 |
| s26 | 0.272544 |
| s27 | 0.226305 |
| s24 | 0.13373 |
| s13 | 0.124305 |
| s15 | 0.118483 |
| s12 | 0.106679 |
| s25 | 0.102046 |
| s45 | 0.065315 |
| s34 | 0.065102 |
| s25 | 0.010639 |
| s36 | 0.005834 |
| s35 | 0.001712 |

**Source :Excel output**




Source : RouteXL: fastest route with multiple stops (online software )

**Figure 13vehicle routing optimization starting from majete ( a)capacity and demand analysis ;(b) Clarke and wright savings algorithm matrix ; (c) final optimized delivery route map**

| | daily demand |
|---|---|
| Kombolcha | 93 |
| Hayq | 70 |
| Wuchale | 81 |
| Wurgessa | 75 |
| Were Ilu | 70 |
| Akesta | 64 |
| Degolo | 64 |
| Bati | 75 |
| capacity | 300 |

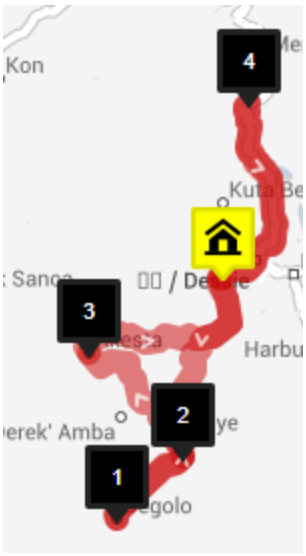
| | estimated distance | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | dessie | Kombolch | Hayq | Wuchale | Wurgessa | Were Ilu | Akesta | Degolo | Bati |
| | dessie | 0 | 0.1806 | 0.2809 | 0.4519 | 0.484 | 0.4844 | 0.4192 | 0.7033 | 0.5081 |
| 1 | Kombolcha | | 0 | 0.2304 | 0.4416 | 0.4687 | 0.5705 | 0.5919 | 0.8107 | 0.3299 |
| 2 | Hayq | | | 0 | 0.2123 | 0.2385 | 0.7586 | 0.6701 | 0.9836 | 0.3786 |
| 3 | Wuchale | | | | 0 | 0.0327 | 0.9355 | 0.7737 | 1.1446 | 0.536 |
| 4 | Wurgessa | | | | | 0 | 0.9678 | 0.6668 | 1.1773 | 0.5464 |
| 5 | Were Ilu | | | | | | 0 | 0.8054 | 0.2473 | 0.8463 |
| 6 | Akesta | | | | | | | 0 | 0.9216 | 0.9216 |
| 7 | Degolo | | | | | | | | 0 | 1.0936 |
| 8 | Bati | | | | | | | | | 0 |

| savings | |
|---|---|
| s12 | 0.2312 |
| s13 | 0.1909 |
| s14 | 0.1959 |
| s15 | 0.0946 |
| s16 | 0.0733 |
| s17 | 0.0733 |
| s18 | 0.3589 |
| s23 | 0.5205 |
| s24 | 0.5264 |
| s25 | 0.0301 |
| s26 | 0.0006 |
| s27 | 0.0006 |
| s28 | 0.4105 |
| s34 | 0.9356 |
| s35 | 0.0007 |
| s36 | 0.0974 |
| s37 | 0.0106 |
| s38 | 0.4239 |
| s45 | 0.0005 |
| s46 | 0.2364 |
| s47 | 0.0099 |
| s48 | 0.4456 |
| s56 | 0.0982 |
| s57 | 0.9404 |
| s58 | 0.1462 |
| s67 | 0.201 |
| s68 | 0.0058 |
| s78 | 0.1178 |

| order | |
|---|---|
| s57 | 0.9404 |
| s45 | 0.9356 |
| s24 | 0.5264 |
| s34 | 0.5205 |
| s48 | 0.4456 |
| s38 | 0.4239 |
| s28 | 0.4105 |
| s18 | 0.3589 |
| s46 | 0.2364 |
| s12 | 0.2312 |
| s67 | 0.201 |
| s14 | 0.1959 |
| s13 | 0.1909 |
| s58 | 0.1462 |
| s78 | 0.1178 |
| s52 | 0.0982 |
| s36 | 0.0974 |
| s15 | 0.0946 |
| s16 | 0.0733 |
| s17 | 0.0733 |
| s25 | 0.0301 |
| s37 | 0.0106 |
| s47 | 0.0099 |
| s68 | 0.0058 |
| s35 | 0.0007 |
| s26 | 0.0006 |
| s27 | 0.0006 |
| s45 | 0.0005 |

**Source :Excel output**









Source : RouteXL: fastest route with multiple stops (online software )

**Figure 14vehicle routing optimization starting from Desssie ( a)capacity and demand analysis ;(b) Clarke and wright savings algorithm matrix ; (c) final optimized delivery route map**

| | daily demand |
|---|---|
| Kobo | 44 |
| Weldiya | 49 |
| Lalibela | 81 |
| Ambassel | 35 |
| Wogel Ter | 49 |
| capacity | 625 |

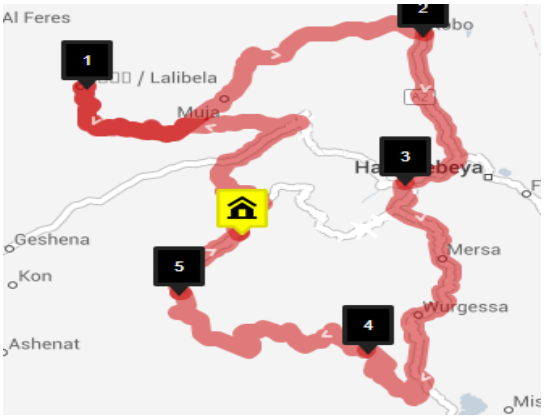
| | x axsi | y axis | demand |
|---|---|---|---|
| Kobo | 12.10997 | 39.419 | 16100 |
| Weldiya | 11.83035 | 39.597 | 17800 |
| Lalibela | 12.03596 | 39.043 | 29600 |
| Ambasse | 11.75424 | 39.241 | 12700 |
| Wogel Te | 11.59393 | 39.21 | 17800 |
| | 11.80424 | 39.273 | |

| | estimatec | Guba E' Mengeriya | 1 Kobo | 2 Weldiya | 3 Lalibela | 4 Ambasse | 5 Wogel Tena |
|---|---|---|---|---|---|---|---|
| | Tikur enc | 0 | 0.338854366 | 0.3259 | 0.3261 | 0.0594 | 0.2195 |
| 1 | Kobo | | 0 | 0.3319 | 0.3828 | 0.3979 | 0.5568 |
| 2 | Weldiya | | | 0 | 0.5912 | 0.3649 | 0.4541 |
| 3 | Lalibela | | | | 0 | 0.1885 | 0.4724 |
| 4 | Ambassel | | | | | 0 | 0.1632 |
| 5 | Wogel Tena | | | | | | 0 |

| savings | |
|---|---|
| S12 | 0.3329 |
| s13 | 0.2822 |
| s14 | 0.0004 |
| s15 | 0.0016 |
| s23 | 0.2692 |
| s24 | 0.0204 |
| s25 | 0.0913 |
| s34 | 0.3571 |
| s35 | 0.0732 |
| s45 | 0.1157 |

| order | |
|---|---|
| s45 | 6.7595 |
| s34 | 6.4114 |
| s15 | 3.6489 |
| S12 | 3.6475 |
| s13 | 3.6253 |
| s14 | 3.4801 |
| s25 | 3.3053 |
| s35 | 3.1372 |
| s23 | 2.9925 |
| s24 | 2.9776 |

**Source :Excel output**




Source : RouteXL: fastest route with multiple stops (online software )

**Figure 15 vehicle routing optimization starting from kobo ( a)capacity and demand analysis ;(b) Clarke and wright savings algorithm matrix ; (c) final optimized delivery route map**

**Table 12 cluster demand and vehicle requirements summary**

| Cluster | Total demand daily | Vehicle capacity | Vehicle needed | Daily distance |
|---|---|---|---|---|
| Tikur enchine | 258 | 625 | 1 | 0.73 |
| Ambo | 891 | 300 | 4 | 3.19 |
| Sokoru | 359 | 1000 | 1 | 8.74 |
| magaala dabasoo | 839 | 2000 | 1 | 40.46 |
| Enewari | 295 | 625 | 1 | 40.20 |
| majete | 482 | 525 | 1 | 4.64 |
| Dessie | 592 | 300 | 2 | 12.75 |
| Guba E' Mengeriya | 258 | 625 | 1 | 41.53 |
| Total | 4138 | | 12vehicles | 155.52 |

| | |
|---|---|
| Total distance | 155.52km |
| Vehicle cost | 9.99 |
| Total cost | 1553.6448 ×300=466,093.44 |

**Summary of Vehicle Routing Optimization**

The Clarke and Wright Savings Algorithm and Excel based analysis were used to optimize the Vehicle Routing Problem (VRP) for the Teklehaymanot and Dessie Moha Plant distribution networks. The main objective of the optimization was to minimize transportation distance, lowering logistics costs, increasing vehicle utilization, and improving overall distribution efficiency across urban and regional delivery networks.

The analysis took into account several consumer locations dispersed along several delivery corridors. The most effective route combinations were determined by calculating savings values using customer demand data and geographic coordinates. Both distribution systems relied on individual direct deliveries from the depot to each client site prior to optimization, which led to long transportation distances, frequent depot returns, high fuel consumption, ineffective vehicle use, and higher operating expenses.

Significant improvements in transportation efficiency were demonstrated by the optimization outcomes. From distribution center , the total transportation cost reduce from **623,868.70 to 466,093.44.**

Overall, the Clarke and Wright Savings Algorithm implementation highly improve the logistics and transportation efficacy and also reduce the total transportation cost, as shown by the comparison of the optimization results before and after. Applying VRP Improved vehicle usage, less fuel consumption, fewer repetitive depot returns, fewer needless trip movements, cheaper transportation costs, and increased delivery efficiency were all benefits of the revised routing system. Additionally, by using less fuel and producing fewer car emissions, the shorter travel distance leads to environmental sustainability.

**Table 13 Comparison of distribution network performance under different optimization methods**

| Performance indicator | Current distribution center | Transportation model | Transshipment model | Vehicle routing (clearke and wright) |
|---|---|---|---|---|
| Total transportation | 23,712,296 | 4,292,000 | 623,868.70 | 466,093.44 |

| | | | | |
|---|---|---|---|---|
| cost | | | | |
| Cost reduction | _ | 19,420,296 | 3,668,131.3 | 157,775.26 |
| Cost reduction (%) | _ | 81.90% | 97.37% | 98.03% |
| Distribution efficiency | Baseline | Improved | More improved | Highest |

## 4.7 Environmental sustainability

The sustainability comparison was conducted based on the results obtained from the Transportation Model, Transshipment Model, and Vehicle Routing Problem (VRP) analysis presented in this chapter. The company's prior distribution system was depends on manual planning and experience-based decision-making, which resulted in operational inefficiencies like redundant routes, underutilized vehicle capacity, needless transportation distance, and increased fuel consumption, according to the results of the optimization analysis and interviews. According to Herize sustainable transportation systems focus on improving operational efficiency while simultaneously reducing environmental impact through better supply chain coordination and optimized transportation activities. (Heizer, 2017)

By distributing goods as efficiently as possible between the Teklehaymanot and Dessie factories and the various market locations, the Transportation Model enhanced sustainability. The transportation cost was 23,712,296 dollar prior to optimization; however, after using Excel Solver to apply the linear programming model, the cost was lowered to 4,292,000 dollar. This improvement demonstrates how optimization helps cut down on pointless transportation-related operations and enhances the effective use of available transportation resources. The concept lowers greenhouse gas emissions and fuel usage by reducing wasteful and long-distance deliveries.

The Transshipment Model created further sustainability improvements by introducing intermediate distribution points into the network. The transportation cost was considerably lowered to Birr 623,868.70as a result of the optimization. By permitting goods to go via intermediate nodes before arriving at their final destinations, the approach enhanced shipping consolidation and decreased repetitive vehicle movements. This decreased empty or partially

loaded trips across the distribution system and increased truck utilization, according to this chapter analysis report. Fuel use, inefficient transportation, and needless trip distances were thereby decreased.

By utilizing the Clarke and Wright Savings Algorithm to improve route sequencing and vehicle assignment, the Vehicle Routing Problem (VRP) model also made a substantial contribution to sustainability by reducing the total transportation cost from 623,868.70 to 466,093.44. The optimized routes increased delivery coordination between client locations and decreased needless trip distance, according to the analysis in Chapter Four. The routing approach satisfied vehicle capacity and customer demand restrictions while minimizing route overlap and reducing overall transportation activity. These upgrades contributed to a reduction in operating inefficiencies, fuel consumption, and travel time. Additionally, more ecologically friendly logistics operations are supported by shorter and more effective routes, which lower carbon emissions. The result integrates with the research that is done by Javanpour et al, which elucidated how efficient transportation planning and sustainable mobility directly reduce costs and carbon emissions (Javanpour et al., 2025) .

The integrated transportation, transshipment and vehicle routing optimization model not only improve the total transportation cost of the distribution network but also contribute to environmental sustainability.

The optimized distribution network reduces the total distance the total carbon emission. Since carbon dioxide emission are directly related to fuel consumption and the distance traveled, this reduction of traveling distance leads to decrease in carbon emissions. Based on this study, the optimized model reduces the total carbon emission by 285.21kg.

# CHAPTER FIVE

## Introduction

This chapter summarizes the stud's basic result, conclusion, and recommendations drawn from analysis of primary data and secondary data.

## 5.1 Summary

This study was aims to integrate sustainable transportation network using  for Moha Soft Drink S.C., focusing on the Teklehaymanot and Dessie plants. The research specifically examined how the application of transportation, transshipment, and vehicle routing models can improve distribution performance while addressing sustainability concerns.

A mixed method research approach was employed. Qualitative data were collected through interviews with key operational staff, including supply chain, fleet, and sales coordinators, while quantitative analysis was carried out using optimization techniques implemented through Excel Solver. This combination allowed the study to give solution for both sustainability and analytical optimization outcomes.

The qualitative result shows that the current distribution system lacks systematic optimization and is mainly experience based. Key factors like fluctuation of demand, vehicle capacity, and transportation cost are not fully the part of strategic planning is carried out. There are also inefficiencies like unused vehicle capacity, unnecessary trips, and inconsistent routing choices were found. By using optimization models, the quantitative analysis addressed these inefficiencies. While the transshipment model improves flow coordination through intermediary nodes, the transportation model reduced shipment allocation costs. Furthermore, the delivery sequence and route efficiency were improved by the vehicle routing strategy. In comparison to the current system, the results showed a decrease in the overall cost of transportation (from 23,712,296 to 4,292,000 using transportation, to 623,868.70 using transshipment, and to 466,093.44using vehicle routing).

Additionally, the study shows that optimization is a strategy for enhancing environmental sustainability as well as a tool for cost reduction. The improved network helps reduce emissions

of gases and fuel consumption by cutting down on the overall travel distance and eliminating pointless journeys.

### 5.2 Conclusion

Based on this study the current transportation and distribution system of Moha Soft Drink Teklehaymanot and Dessie plant is operationally functional but strategically inefficien**t**. The absence of a structured optimization framework results in increased transportation costs, poor vehicle utilization, and unnecessary environmental impact.

Furthermore, the implementation of optimization models leads to measurable improvements in efficiency, including cost reduction, better route selection, and improved fleet utilization. These improvements directly enhance the company's operational performance and competitiveness.

From a sustainability perspective, the optimized distribution network supports environmentally responsible logistics operations. Reduced fuel consumption and shorter travel distances contribute to lower greenhouse gas emissions, aligning operational efficiency with sustainability goals.

Finally, the study demonstrates that data-driven decision-making is essential for modern supply chain management. Organizations that rely on analytical models rather than intuition are better positioned to achieve long-term efficiency and sustainability.

## 5.3 Recommendation

In accordance with the goals and findings, the research suggested the following:

- Applying optimization-Based Decision making algorithms like (transportation, transshipment, and vehicle routing) as part of its logistics planning process. Optimization models value in the form of transit time reduction and delay and general satisfaction with the on-time delivery rate. The factory shall coordinate closely with the service provider to ensure a maximization of savings in delivery costs through efficient planning and delivery strategy. Improvements in transparency and the communication process between the institute and the service provider shall further rationalize operations and reduce delivery time through enhanced use of technology.

- The company should improve its method from manual and experience based planning to technology supported systems. Implementing routing software or advanced decision support tools ( for example excel solver ,RouteXL) will enable on time and accurate planning based on cost, demand, capacity and distance.
- Moha industry should use advanced logistics technologies for selecting route, vehicle and managing demand fluctuation. Additionally, transportation process should implement digitalization and automation.
- The company should consider establishing transshipment depot so that it would reduce transportation cost and reduce the lead time. Properly designed transshipment points that can reduce long transportation distances and enhance responsiveness to regional demand.
- Sustainability should be part of strategic planning of the factory in order to survive the competitive nature of the market also as a core objective in transportation decisions. The company should control fuel consumption and emissions, optimize routes not only for cost but also for environmental impact and also to explore another options like cleaner and energy efficient transportation alternatives in the long term.

## 5.4 Suggested Further Research

- Further studies could expand the scope by applying multi objective optimization models that at the same time consider cost, environmental impact and service level.
- Applying advanced technology such as block chain for demand forecasting also for planning, machine learning for warehouses and big data analytics for maintaining and analyzing big data could be explored.

  This research focuses on two plant case study (Moha Soft Drink teklehaymanot and Dessie plant only), which may limit generalizability. Future studies could do comparative analyses across different plant of Moha or different industries.

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## Appendix 1: Interview Questions

# Addis Ababa University School of Commerce

Department of Logistic and Supply Chain Management Graduating Program

My name is Etsubdink Alemayehu. Iam graduating student at addis ababa university school of commerce. The objective of this research is to study to collect qualitative insights from key personnel (supply chain coordinators, sales coordinator, fleet coordinator) regarding the **"Sustainable Transportation Network Design (The Application of Transportation, Transshipment and Vehicle Routing Problem Solving Algorithms to Solve Moha Soft Drink Teklehaymanot and Dessie Plant)".** Your answers will stay private because they will be used to create overall results which will be disclosed. You have the right to answer any question you wish or skip any question you choose and you can end your participation whenever you want. I will record the interview for note-taking purposes to achieve accurate results after you grant me your consent.

**Estimated Duration**

- 30–50 minutes per interview

**Interview Mode**

- Face-to-face / semi-structured and also with phone.

**Current Distribution Routes and Network Structure**

1. Can you describe how the distribution routes from the Teklehaymanot Plant (Dessie plant) are currently organized?

- Are the routes fixed/specific, or do they change frequently?
- Are there clearly defined territories or zones assigned to vehicles/drivers/agents?

2. How many main distribution routes / delivery territories does the Teklehaymanot Plant (Dessie plant) currently operate?

- approximate number in Addis Ababa vs. routes to other cities

3. What kinds of areas (key distributer) are covered by each type of route (urban Addis Ababa vs inter-city / regional)?

**Vehicle Fleet and Capacity**

4. What types of vehicles are mainly used for distribution from this plant?

5. What is the typical carrying capacity of the most commonly used vehicles?

6. Approximately how many vehicles (company-owned + agent-owned) are actively used for distribution from Teklehaymanot Plant on a typical day/week?

**Responsibility and Efficiency in Distribution**

7. Who is mainly responsible for planning and assigning vehicles/routes on a daily/weekly basis?

(e.g., supply chain coordinator, transport manager, sales team, others)

8. How are vehicle and drivers assigned to specific routes or orders?

- Is there a standard method or software used to decide which vehicle goes where?

9. What do you consider to be the biggest challenges or inefficiencies in the current way vehicles are assigned and routes are planned?

**Sustainability Awareness and Practices**

10. Does the company concerned about the environmental impact of distribution activities (e.g., fuel consumption, emissions, traffic congestion)?

11. Are there any methods that are used by the company to reduce fuel use, emissions, or making distribution more sustainable?

(e.g., route selection, vehicle maintenance schedules, driver training, etc.)

**Warehousing and Transshipment**

12. is there and intermediate depot or transshipment point before products reach the final retailer, are there any intermediate warehouses, depots, or distribution centers used?

- If yes, where are there location? How many? What is their main purpose?

13. How does the using intermediate points affect transportation cost, vehicle utilization, and delivery time?

**Software, Systems, and Order Management**

14. What software or tools are currently used by the company to manage orders, plan routes, track vehicles, or optimize distribution?

15. If any software use what is the strength and the weakness of the software?

16. Is there any future plan introduce by the company new tools or software for better route planning or cost and fuel optimization in the near future?

**Closing Questions**

17. Is there anything else about the current distribution system of moha soft drink which include vehicles, routes, warehouses, or sustainability practices that you think is important for this study to know?

18. Do you have any suggestions on how the distribution system could become more efficient or sustainable?

**Thank you for your precious time**