HAWASSA UNIVERSITY

INSTITUTE OF TECHNOLOGY

FACULTY OF MANUFACTURING

DEPARTEMENT OF INDUSTRIAL ENGINEERING

DESIGNING DISTRIBUTION NETWORK FOR HIGHLY DEMANDED COMMODITY:CASE OF SOUTH SPRING WATER IN SIDAMA NATIONAL REGIONAL STATE

A THESIS SUBMITTED FOR M.SC. IN INDUSTRIAL ENGINEERING AND LOGISTIC MANAGEMENT

BY

TSEGAABTESEMAHATIYA

MAY, 2022

HAWASSA, ETHIOPIA

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN INDUSTRIAL ENGINEERING AND LOGISTIC MANAGEMENT

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ADVISORS' APPROVAL SHEET

This is to certify that the thesis entitled **"Designing a Distribution Network for Highly Demanded Commodity: A Case Of South Spring Water in Sidama National Regional State"**submitted in partial fulfillment of the requirements for the degree of **Master's** with specialization in **Industrial Engineering and Logistic Management,**the Graduate Program of the **Department of Industrial Engineering,**and has been carried out by **TsegaabTesema** (ID.No.**GPIELMR/0014/112),** under our supervision. Therefore we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the department.

Name of major advisor	Signature	Date
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EXAMINERS' APPROVAL SHEET

We, the undersigned, members of the Board of Examiners of the final open defense by **Tsegaab Tesema** have read and evaluated his thesis entitled **"Designing a Distribution Network for Highly Demanded Commodity: A Case Of South Spring Water in Sidama National Regional State**, and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree.

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DECLARATION

I hereby declare that this M.Sc. thesis entitled **"Designing a Distribution Network for Highly Demanded Commodity: a Case Of South Spring Water in Sidama National Regional State** is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

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Signature: ____________________

This MSc thesis entitled **"Designing a Distribution Network for Highly Demanded Commodity: a Case of South Spring Water in Sidama National Regional State** has been submitted for examination with my approval as thesis advisor.

Name: **Fentahun Moges (PhD)**

Signature: _______________

Place and Date of Submission: ______________________, Hawassa Ethiopia

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Acronyms/Abbreviations

CST	Central sales tax
MILP	Mixed integer linear programming
SPW	South Spring Water
LCM	Location scoring method
MTS	Make to stoke
RVV	Relative value vector
MTO	Make to order
AHP	Analytical Hierarchy process
VFM	Value for money
TOPSIS	Technique for order preference by similarity of ideal solution
DEA	Data envelopment analysis
SAW	Simple additive weighting
ANP	Analytic network process
MCDM	Multi criteria decision method
MODM	Multi Objective Decision making
MADM	Multi Attribute Decision making
FAHP	Fuzzy Analytical Hierarchy process
SNRS	Sidama National Regional State
COG	Center of Gravity

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Abstract

A distribution is one of a key activity that has a direct impact on the success and the overall profitability of a given supply chain. If a distribution of a given product managed properly, it will have a great impact on both the success and customer satisfaction of a given SC. However, there are many manufacturing companies in Ethiopia, most of them do not have properly designed distribution network. This research is intended to design a new distribution network for a water bottling company located in Sidama National Regional State Arbegona Woreda..To distribute a given product in cost effective manner there should some decisions be made which include number of regional warehouses, location of regional warehouse and transportation cost to and from the regional distribution. So the research decides the number and the locations of regional distribution centers by utilizing FAHP method. After the locations of the RDCs found, a new distribution network will be proposed and the Transshipment was modeled based on a newly proposed distribution network and solved by using software package find out the optimum transportation cost. After the Transshipment model solved and optimum solution was found the cost effective RDCs was assigned to different demand locations in the region. Finally, the new cost effective distribution network diagram was developed and the cost of transportation was compared to the existing transportation cost of the company to cover all demand location and the newly designed network saves the company 13.7 million ETB annually which is being wasted due to ineffective distribution network.

Key words: Distribution network, Regional distribution center, supply chain, Transportation cost, Warehouse Facility

CHAPTERONE: INTRODUCTION

1.1.Background of the study

In today's rapidly changing economic and political conditions, it is a big challenge for companies to constantly evaluate and optimally configure their distribution network. An important strategic issue related to the design/re-design and operation of a physical distribution network in a supply chain system is the determination of the best sites/facilities for intermediate stocking points or warehouses (Melo et al., 2009).

The use of warehouse (facility) provides a company with flexibility to respond changes in the marketplace and can result in significant cost savings owing to economies of scale in transportation or shipping costs, inventory costs, tax structure while moving the product from factory to warehouses located across the states within the country. In addition, the combined facility location/network design problems are useful for modeling a number of situations in which trade-offs between facility costs, network design costs and operating costs must be made (Melkote and Daskin, 2001).

Distribution refers to the steps taken to move and store a product from the supplier stage to a customer stage in the supply chain. Distribution is a key driver of the overall profitability of a firm because it directly affects both the supply chain cost and the customer experience. Good distribution can be used to achieve a variety of supply chain objectives ranging from low cost to high responsiveness. As a result, companies in the same industry often select very different distribution networks (Chopra and Meindl, 2001.)

The distribution network is an important part in the supply chain management and the distribution network design is an important strategic decision in supply planning and management. The problems of a distribution network design involve both the optimization of the flows of goods and the improvement of the existing distribution network (Ambrosino and Scutella, 2005). A good distribution network design can be used to achieve a variety of supply chain objectives ranging from low cost to high responsiveness (Chopra, 2003; Gunasekaran and Ngai, 2004; Liu and Hao, 2006).

If a distribution network or a distribution strategy of a given company is poor, it has a negative impact on overall performance of its supply chain and also it highly affect the profitability of the company and customer satisfaction will be negatively impacted (Yetimwork, 2014).

Any organization to be effective there should be effective distribution management process to convey finished products from the manufacturer to the final consumers. This is because without having standardized distributor the best product will not be delivered and the marketing mix will break down and fail (Addis 2018).

However, some products like breweries and bottled water like "Yes" have a good distribution network and have good distribution strategy. Even though there are methods to design a good distribution network and infrastructures to implement them, many manufacturing companies in Ethiopia distribute their products in traditional and heuristic approach. This has been leading many companies to poor supply chain performance and costing them a lot of money that should have been earned (Yetimwork, 2014).

Therefore, this research project is to investigate the current distribution strategy of the company and design a new distribution network for a South Spring Water product of Garamba Bottling S.C, which is one of water bottling companies in Ethiopia located in SNRS.

1.1.1 Background of the company

Garamba bottling is a company that is located in eastern part of SNRS, Arbegona Woreda. The company had launched its product by the year 2019 called south spring water. The product of the company, SPW, is being produced with three different sizes which are: - 0.6 L, 1.2 L, and 2L.

The company is owned by Private Investor Mr. Biruk who also has many investments within a country. As company Deputy Manager Mr. Anteneh informed the researcher, the company's initial investment was birr 400,000,000 which is from loan from national bank of the country.

The company owns different type of vehicles for distribution and inbound logistics of raw materials. And as information from a warehouse manager of the company Mr.Fire, the company own 16 truck trailers, 2 FSR and 2 Isuzu.

The raw water from Garamba Mountain springs, which is located about 4km away from the facility, is transported directly to the plant through pipeline transportation. Then the water further processed with some chemicals and bottled by the machine in different sizes based on demand information and is being supplied to the market.

The company works in two shifts 24 hours a day and seven days a week. The company implements both MTS and MTO marketing strategies. Highly demanded product size of the company is 1.2L bottle so if there is no order the company produce and stores 1.2l bottle. When the order is in place for different size then the production will shifted to the ordered size.

Currently there is one active production line in the company with production capacity of 1660 bottle per hour (1.2L size). The product is being packed together six bottles as one pack so the production capacity of the line is 277 pack per hour which is 40,000 pack per day when the line is performing up to its full potential.

The company is under construction for expansion of the line and another line with equal capacity is being installed. 80 % of the project is completed and the company will start producing using two lines next year. When the new line starts producing the production capacity of the company will be doubled this are 80,000 packs per day.

1.2.Statement of the Problem

Manufacturing companies supply chain is highly dependent on its distribution strategy and distribution network and distribution can be considered as heart of manufacturing industries supply chain (Okunade and Daodu, 2020).

Distribution is a key driver of the overall profitability of a firm because it directly affects both the supply chain cost and the customer experience. Good distribution can be used to achieve a variety of supply chain objectives ranging from low cost to high responsiveness and for overall success of a given supply chain (Okunade and Daodu, 2020).

The effect of distribution process on supply chain cost and customer satisfaction is huge. This makes the distribution process a crucial decision for supply chain management. Therefore, optimum distribution network design helps organizations in minimization of delivery cost and maximization of customers' satisfaction (Ceyhun et.al 2020).

During a travel to different Demand points' in the SNRS, the researcher noticed high demand and supply unbalance for the product SPW and the researcher tried to collect some information from the retailer and consumer of the product, there is high shortage of the product in most of Demand points'.

From the information from the company officials and reviewing the sales record of the company, the majority of product (80%) in the region is shipped to Hawassa city and yet the company still having a trouble meeting the target customer demand by using only one warehouse located at Hawassa city.

The company directly supplies only a few Demand points ‘on the behalf of the agent and the majority of Demand points in the region gets the product from Hawassa city and the retailers of the product in the region have many complaints about the way they are getting the product and high cost of transportation to do so, which will in turn have direct impact on customer satisfaction and the performance and profitability of the whole supply chain of the company.

Even though SPW is highly demanded products in SNRS, the company, Garamba Bottling, has not designed a proper distribution network giving the fact that it is newly established and it is implementing some traditional approaches which is not responsive and is also with high lead time considering the travel distance from the factory.

The study from Okunade and Daodu, (2020) showed that distribution network design with intermediaries gives a better result than that of direct shipment. Also, the location(s) of the intermediate point(s) is critical in that it ensures the total cost of distribution is minimized.

Therefore this study intended to design the distribution network that minimizes cost of distribution while balancing the supply and demand in SNRS.

1.3.Research Questions

At end of this research, the following research questions were answered:

- What does an existing distribution network of the company looks like?
- Where should the company locate the regional warehouses?

- What adjustment should be made to existing distribution network to meet target customers demand with in SNRS?
- What is the optimal cost of distribution of newly designed network to meet demand of target customer within SNRS?

1.4.Objectives

1.4.1. General Objective

The aim of this research is to design a new distribution network that can minimize the total cost of distribution based on predicted demand for South Spring Water of Garamba Bottling Company.

1.4.2. Specific Objectives

- To assess existing distribution network of the company.
- To locate the regional DCs or warehouses for the company.
- To propose and design a new distribution network for the company.
- To calculate optimal distribution costs using a newly designed distribution network for the case company.

1.5.Scope and Limitations of the Study

This research focused on distribution network design for South Spring Water, Garamba Bottling S.C. In addition, analysis and interpretations of the data of the survey assessed whole sellers in different Demand points in SNRS and the main limitation is the research was limited only in SNRS due to different factors like time and budget.

1.6.Significance of the Research

This distribution network design maximizes the profitability by minimizing the cost of transportation to distribute the SPW within SNRS and it also improves the level of satisfaction of the customers of the company Garamba Bottling.

Similar companies that are being constructed in the area, Arbegona Woreda, can also implement this newly designed distribution network to distribute their product within SNRS and can and will minimize their cost of transportation by doing so.

The findings of the research will also give insight on how to decide on the distribution network type for researchers and students interested on designing cost effective distribution network for highly demanded commodity.

Lastly, this research project aimed at adding a valuable contribution to the industrial engineering literature in general and to draw conclusions and give directions based on the research findings to indicate further study.

1.7. Organization of the Research

This thesis is categorized into five chapters. The first chapter concentrates on introductory parts of the paper that mainly pinpoints the statement of the problems and objective of the study. The second chapter provides related literature review with specific emphasis to theoretical, methodological and empirical aspects. The third chapter also deals with research methodology and design. The fourth chapter includes data presentation and analysis of the descriptive and regression results. Finally the fifth chapter has focused on conclusion and recommendations on the basis of the research outcomes.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

Highly demanded products are products that are consumed within a short period and are quickly replaced. It has a large market because it is highly consumed on daily basis. Highly demanded products require an efficient supply chain to drive its distribution operations thus ensuring minimized cost of distribution operations as well as maximized customers' satisfaction (Leahy et.al, 2011).

Distribution network design issue has been researched for a decades by different researchers, scholars, students and manufacturing companies' for purpose of understanding issues related to it. Since this particular study is about designing distribution network, the literatures closely related this particular study was reviewed and the literature gap to be filled by the study was identified in the following subsections.

2.2. Distribution and distribution network

Physical distribution network is the term used to describe the method and means by which a product or a group of products are physically transferred, or distributed, from their point of Production to the point they are made available to the final customer. In general, this end point is a retail outlet, shop or factory, but it may also be the customer's house, because some channels bypass the shop and go direct to the consumer. (Rushton et.al, 2010)

The distribution network is an important part in the supply chain management and the distribution network design problem is an important strategic decision in supply planning and management. The problems of a distribution network design involve both (a) the optimization of the flows of goods and (b) the improvement of the existing distribution network (Ambrosino and

Scutella, 2005). A good distribution network design can be used to achieve a variety of supply chain objectives ranging from low cost to high responsiveness (Chopra, 2003; Gunasekaran and Ngai, 2004; Liu and Hao, 2006).

During the configuration/reconfiguration of the distribution network design, operation managers and planners need to address questions such as where to produce, where to open the warehouses, and how should it be distributed through the distribution network. The complexity of this problem increases for these operations managers when the selling model of the company is multi-echelon, in which the products are shipped from the factories to warehouses and from there distributed to the customers through the distributors. In addition, the decision-makers need to consider the effects of taxes during the design of distribution network because taxes add to their bottom-line cost of distribution. Sometimes, it is possible for managers to avoid these taxes by a suitable network design for their supply chain.(Mathirajan et. al.2015)

Distribution still offers a new frontier for competing successfully, especially if the emphasis is placed on the design and management of superior marketing channel systems to provide excellent customer services. Yet designing optimal marketing channel systems to boost sales, formulating innovative distribution strategies and managing channels system effectively is not a simple task (Obaji, 2011).

2.2.1 Types of distribution channel or network

Channels of distribution can be divided into the direct channel and the indirect channels. Indirect channels can further be divided into one-level, two-level, and three-level channels based on the number of intermediaries between manufacturers and customers. (Pahwa, 2021)

Direct Channel or Zero-level Channel (Manufacturer to Customer)

Direct selling is one of the oldest forms of selling products. It doesn't involve the inclusion of an intermediary and the manufacturer gets in direct contact with the customer at the point of sale.

Indirect Channels (Selling Through Intermediaries)

When a manufacturer involves a middleman/intermediary to sell its product to the end customer, it is said to be using an indirect channel. Indirect channels can be classified into three types:

One-level Channel (Manufacturer to Retailer to Customer): Retailers buy the product from the manufacturer and then sell it to the customers.

Two-Level Channel (Manufacturer to Wholesaler to Retailer to Customer): Whole salers buy the bulk from the manufacturers, break it down into small packages and sell them to retailers who eventually sell it to the end customers.

Three-Level Channel (Manufacturer to Agent to Wholesaler to Retailer to Customer): Three level channel of distribution involves an agent besides the wholesaler and retailer who assists in selling goods.

Dual Distribution

When a manufacturer uses more than one marketing channel simultaneously to reach the end user, he is said to be using the dual distribution strategy. They may open their own showrooms to sell the product directly while at the same time use internet marketplaces and other retailers to attract more customers.

The case company, Garamba Bottling, is already implementing dual distribution channel from the above list of channels in which it sells its product directly in Hawassa city and through agent in the rest of demand areas within the study area and the network is two echelon distribution networks in which there is a transshipment point at Hawassa city.

The existing distribution network of the company can be considered as transshipment problem since it has a transshipment point in Hawassa city.

The Transshipment Problem has a long and rich history, dating back to the medieval times when trading started becoming a mass phenomenon. It was first introduced by Orden (1956) in which he formulated an extension of the original transportation problem to include the possibility of transshipment.

2.2.2 The Transshipment problem

The transshipment problem is a unique Linear Programming Problem. From the unset of its introduction by A. Orden in 1956, its acceptance and/or use has greatly broadened over the years. The initial problem took into consideration the use of intermediate points through which shipments were to be allowed to pass through to the needed destination. From his work the transshipment problem was and still is the ideal for solving shortest route problems.

Rhody (1963) considered the transshipment problem as a reduced matrix model while King and Logan (1964) went further to formulate an alternative model that allows simultaneously the transportation of main goods through processors to the market as end products as a transshipment problem. Hurt and Tramel (1965) adopted the studies of King and Logan as an alternative formulations of the transshipment problem within the framework of the transportation model but proposed that there was no need for the subtraction of artificial variables.

The transshipment problem considers that within a given time period each shipping source has a certain capacity and each destination has certain requirements with a given cost of shipping from source to destination. The Objective Function is to minimize total transportation costs and satisfy destination requirements within source requirements (Gupta and Mohan, 2006).

Hmiden et al. (2009) studied the transshipment problem that is characterized by the uncertainty relative to customer demands and transfer lead time. They consider a distribution network of one supplier with several locations selling a product. They used expert judgments to evaluate customer demands and the transfer lead time which they represented by fuzzy sets. The purpose of their study was to identify a transshipment policy that takes into account the fuzziness of customer demands and transfer lead times and to determine the approximate replenishment quantities which minimize the total inventory cost. They proposed a new transshipment policy where the transshipment decision is made within the period and the possible transshipment decision moments belong to a fuzzy set to achieve their aim. For the expert judgments they also consider the decision maker behavior types (pessimistic and optimistic) to determine the precise transshipment decision moment and the transshipment quantity.

Ameln and Fuglum (2015) introduced the use of transshipment to the liner shipping network designs which was less common a few decades ago. They noted that as at 1991 transshipment was not included in the studying route planning for liner shipping network.

Notteboom and Rodrigue (2008) stated that the use and influence of transshipment on the liner shipping network design was described and whether or not transshipment operations are allowed between the routes differ based on each researcher while Meng et al. (2014) noted that 8 out of 12 of the studies on fleet deployment did not consider transshipment.

Reinhardt and Pisinger (2011) argue that transshipment of goods is frequently occurring in liner shipping and the associated cost should not be ignored when designing the network. They claim that their paper presents the first exact solution methods to the LS-NDP (Liner Shipping Network Designs Problem) with transshipment cost.

The General transshipment Model

The general linear programming model for a transshipment problem is

$$Min \sum_{allarcs} c_{ij}\ x_{ij} \qquad (2.1)$$

Subject to:

$$\sum_{arcout} x_{ij} - \sum_{arcin} x_{ij} = s_i \text{Originnodesi} \qquad (2.2)$$

$$\sum_{arcout} x_{ij} - \sum_{arcin} x_{ij} = 0 \text{ Transhipment nodes i} \qquad (2.3)$$

$$\sum_{arcout} x_{ij} - \sum_{arcin} x_{ij} = d_i \text{ Destination nodes j} \qquad (2.4)$$

Where:

X_{ij} = amount of unit shipped from node i to node j

C_{ij} = cost per unit of shipping from node i to node j

S_i = supply at origin node i

d_i = Demand at sink node j

From the above model we understand that the supply point is the point(s) that can only send goods to another point(s) but cannot receive goods. While the demand point(s) is/are also a point(s) that can only receive goods from other points but cannot send any. Then the transshipment point(s) is that point(s) that can receive goods from other points and also send goods to other point(s). In this model all goods within the network must be transported or shipped without any reservations until all constraints are fully satisfied.

2.2.3 Needs for distribution Network Design

Distribution network design in supply chain helps in determining the least cost in the distribution of products (which could be raw materials, semi-finished goods or finished goods) between echelon of supply chain such that demand at warehouses and capacity at the plants are satisfied.(Straka, 2005)

In today's world of mass production, there is always a pressing need for intermediaries of one type on the other from enabling the goods to reach the customer (Sahu and Raut, 2003).

Rosen Bloom (1995) has pointed out many situations that can indicate the need for a channel design as follows:-

- ✓ Developing a new product or product line. If existing channels for other products are not suitable for the new product or product line, a new channel may have to be set up on the existing channels modified in some fashion;
- ✓ Aiming an existing product at a new target market;
- ✓ Making a major change in some other component of marketing mix;
- ✓ Establishing a new firm, from scratch or as a result of mergers or acquisition.
- ✓ Opening up new geographic area;
- ✓ Meeting the challenge of conflict or other behavioral problem.

The above list, although by no means comprehensive, offers and overview of the more common conditions that may require the channel manager to channel design decisions.

According to (Teo.et.al, 2004) in today's competitive market, a company's distribution network must meet service goals at the lowest possible cost. In some instances, a company may be able to save millions of dollars in logistics costs and simultaneously improve service levels by redesigning its distribution network. To achieve this, an ideal network must have the optimum number, size, and location of warehouses to support the inventory replenishment activities of its retailers. This statement calls for sophisticated facility location models to determine the best supply chain configuration.

This study focused on designing the distribution network for one of water bottling companies in Ethiopia to minimize its cost of distribution while improving the service level of the company by incorporating facility location decisions and transportation cost minimization strategies.

2.3. Facility Location

An ordinary initial step for the analysis of location choices is to ask where a particular economic activity will be located as long as we know the locations of all other activities (Beckmann, 1968). This problem has been comprehensively studied in the literature for years, and it is referred as the plant location problem, or facility location problem. A basic facility location problem requires locating a number of facilities to supply a set of customers and the objective is to minimize the cost of locating process and to assign the customers to them with respect to some set of constraints (Kodali and Routroy, 2006). In other words, according to Aswathappa et.al (2010) “Plant location is the function of determining location for a plant for maximum operating economy and effectiveness."

Facility location is a component in operations management related to the location of new facilities in order to optimize at least one objective such as cost, profit, distances, service, or waiting time. There is no restriction for location choice from an application point. It can be used for many areas including public and private facilities, military environment, national and international scopes (Farahani et. al., 2010).

The "location problem" refers to modeling, formulation, and solution of a group of problems that are defined as locating the facility in a given space. Deployment, positioning, and locating are often used as synonymous. There are four components that describe location problems: customers, who are already located at points, facilities that are to be located, a place in which customers and facilities are to be located, and a measure that refers to distances or time between customer and facilities (Farahani and Hekmatfar, 2009).

It is not easy to change the location very often. Selecting the appropriate facility among a given set of alternatives is a difficult work requiring both qualitative and quantitative factors (Athawale and Chakraborty, 2010). It is a broad and enduring subject, affecting several operational and logistical decisions, and the location projects generally involve long-term investments. For instance, the location of a very expensive automobile factory cannot be changed due to changes in demands, transportation, and raw material price. Hence a successful facility location process would enable a leading edge to the company (Kodali and Routroy, 2006).

On the other hand, a bad facility location is a burden, and it may bankrupt the company. Once a mistake is made for the location of facility, it becomes extremely difficult and costly to change it especially in large facilities (Aswathappa et. al., 2010). Therefore, decision makers must select not only a well performing facility for the current situation, but also a profitable facility for the lifetime of the company (Farahani and Hekmatfar, 2009).

2.3.1 Location Decision Methodology

In order to determine which methods are most appropriate for establishing the model of a decision, we should consider the kind and amount of the available information. Decision making methods can be listed under three conditions that are; certainty, uncertainty, and risk(Kumar and Suresh, 2009).

We mostly came across multi-criteria mathematical programming models that are used by making several assumptions in input data depending on perceptions of decision makers. It is known that facility location selection problem is a multi-criteria decision problem; therefore, the mathematical models are used in multi-criteria decision making, which is more based on certain data. On the other hand, the conditions under uncertainty/risk are handled by using multi-attribute decision-making methods, which will be explained in the following part.

Utility theory, which allows decision makers to incorporate their own experiences, can also be used in the decision making process. Yet in our case, it is a new facility location with no background experiences. Simulation is also not possible to be used due to high cost of analysis and lack of time in the project. In case of heuristic methods, we do not consider our problem very complicated as it is solved by means of heuristic methods, since we only handle the first phase of facility location process.

2.3.1.1Multi-criteriadecisionmaking ***(***MCDM***)***

Since the problems that are faced in companies are not generally single and simple, simple decision-making methods are not sufficient for companies' complicated problems. In that point multi-criteria decision-making is very suitable in order to consider and compare many factors and alternatives. Multi-criteria decision making is the most well-known decision-making, and it is a branch of operations research, which deal with decision problems under a number of decision criteria (Triantaphyllou et al., 1998).

MCDM is a normative way of decision-making where there is one decision maker with multiple criteria problem. Its aim is to consider the way the decision maker looks at the multi-criteria

problem. In order to do that, a mathematical model must be constructed, since the amount of information in multi-criteria problem is too much for a human to make the whole process.
This can be best done by letting decision maker focus on smaller parts of the problem. The way the decision maker looks at the multi-criteria problem is also defined as the decision maker specific data (Keyser and Springael, 2010).

According to many authors multi-criteria decision-making is divided into two categories as multi-objective decision-making (MODM) and multi-attribute decision-making (MADM), which is relatively more popular. MADM problems can be broadly described as “selection problems" and MODM as “mathematical programming problems." MADM depends on selecting the best possible alternative from a finite set of predetermined alternatives. It can also be referred as the multiple criteria methods for finite alternatives.

Since this particular study incorporates selecting facility locations from finite number of candidate locations, it is MADM problem and analyzed by applying one of MADM method that was suitable for this particular case decided by experts involved. The MADM is explained in following sections.

2.3.1.2. Multi Attribute Decision Making Problem

MADM is a well-known branch of decision-making. It differs from MODM problems, which design a best alternative by considering the tradeoffs within a set of constraints whereas MADM makes the selection among several courses of action by considering multiple but usually connecting attributes (Kahraman, 2008). MADM focuses on problems with discrete decision spaces with infinite number of alternatives, explicitly known in the beginning of the process (Triantaphyllou et al., 1998). Many MADM problems are considered with both quantitative and qualitative attributes. In many cases, the qualitative attributes, can only be evaluated by human judgment, which is subjective and related to uncertainty (Guo et. al., 2009).

Solving a MADM problem requires sorting and ranking. MADM approaches can be deemed as alternative method to combine the information in problem solving matrix together with the information coming from the decision maker for making a last ranking, sorting, screening, and selection among several alternatives (Kahraman, 2008).

For classification of MADM methods there could be many ways, one classifies them according to the data they use. Those are deterministic, stochastic, fuzzy MADM methods, or a combination of the data types. Other way of classification is based on the number of decision makers in the decision process.

For example, the single decision maker deterministic MADM methods are WSM, AHP, revised AHP, WPM, and TOPSIS that will be explained below (Triantaphyllou et. al., 1998).
In their book, Hwang and Yoon (1981) have given 14 MADM methods, and Kahraman (2008) added five more methods in his book. Those are Dominance Method, Maxi-Min Method, Maxi-max Method, iniMax (Regret) Method, Conjunctive (Satisfying) Method, Compromise Programming, Disjunctive Method, Lexicographic Method, Lexicographic Semi-order Method, Elimination by Aspects, Linear Assignment Method, Simple Additive Weighting (SAW) Method, Weighted Product Method, Non-traditional Capital Investment Criteria, TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), Distance from Target, Analytic Hierarchy Process (AHP), Outranking Methods (ELECTRE, PROMETHEE, ORESTE), Multiple Attribute, Utility Models, Analytic Network Process (ANP), Data Envelopment

Analysis (DEA), Multi Attribute Fuzzy Integrals. Since there are so many numbers of methods, we will introduce the three most common methods.

Simple Additive Weighting (SAW) Method

Simple additive weighting method it is one of the simplest method. Every alternative is ranked according to the sum of their cardinal weights preference. In order to find the attribute weights, it is necessary to multiply the performance score with attribute importance (Kahraman, 2008).

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution)

TOPSIS chooses the best attributes of the decision matrix among all the alternatives to create an ideal solution. Then the alternative that is closest to the ideal solution and at the same time farthest from the non-ideal solution is chosen (Kahraman, 2008). To make this selection TOPSIS method creates an index that combines the closeness and remoteness of an alternative to the ideal solution and to the negative-ideal solution respectively (Abu, 2009). An example of the use of TOPSIS can be found in the research of Farahani and Hekmatfar (2009), where they apply a fuzzy TOPSIS to solve problems with inaccurate qualitative and quantitative data.

THE BASIC PRINCIPLES OF THE FAHP

Fuzzy Analytic Hierarchy Process (F-AHP) embeds the fuzzy theory to basic Analytic Hierarchy Process (AHP), which was developed by Saaty (1980). AHP is a widely used decision making tool in various multi-criteria decision making problems. It takes the pair wise comparisons of different alternatives with respective to various criteria and provides a decision support tool for multi-criteria decision problems. In a general AHP model, the objective is in the first level, the criteria and sub criteria are in the second and third levels respectively. Finally the alternatives are found in the fourth level (Kilincci&Onal2011).

Since basic AHP does not include vagueness for personal judgments, it has been improved by benefiting from fuzzy logic approach. In F-AHP, the pair wise comparisons of both criteria and the alternatives are performed through the linguistic variables, which are represented by triangular numbers (Kilincci, O., &Onal, S. A., 2011).

One of the first fuzzy AHP applications was performed by van Laarhoven and Pedrycz (van Laarhoven et.al, 1983).They defined the triangular membership functions for the pair wise comparisons. Afterwards, Buckley (1985) has contributed to the subject by determining the fuzzy priorities of comparison ratios having triangular membership functions. Chang (1996) also introduced a new method related with the usage of triangular numbers in pair-wise comparisons.

Although there are some more techniques embedded in F-AHP, within the scope of this study, Buckley's methods are implemented to determine the relative importance weights for both the criteria and the alternatives. The steps of the procedure are as follows:

Step 1: Decision maker compared the criteria or alternatives via linguistic terms shownTable2.1

Table2.1: Linguistic terms and the corresponding triangular fuzzy numbers

Saaty scale	**Definition Fuzzy**	**Triangular Scale**
1	Equally important	(1,1,1)
3	Weakly important	(3,4,5)
5	Fairly important	(5,6,7)
7	Strongly important	(6,7,8)
9	Absolutely important	(9,9,9)
2		(1,2,3)

4	The intermittent values	(3,4,5)
6	between two adjacent scales	(5,6,7)
8		(7,8,9)

According to the corresponding triangular fuzzy numbers of these linguistic terms, for example if the decision maker states "Criterion 1 (C1) is Weakly Important than Criterion 2 (C2)", then it takes the fuzzy triangular scale as (2, 3 and 4). On the contrary, in the pair wise contribution matrices of the criteria, comparison of C2 to C1 will take the fuzzy triangular scale as (1/4, 1/3, 1/2).

The pair wise contribution matrices are shown in Eq.2.5, where $\tilde{d}_{ij}^{k}$ indicates the kth decision maker's reference of ith criterion over jth criterion, via fuzzy triangular numbers. Here, "tilde" represents the triangular number demonstration and for the example case, $\tilde{d}_{12}^{k}$ represents the first decision maker's preference of first criterion over second criterion, and equals to, $\tilde{d}_{12}^{k} = (2, 3, 4)$

$$\tilde{A}^{k} = \begin{bmatrix} \tilde{d}_{11}^{k} & \tilde{d}_{12}^{k} & \dots & \tilde{d}_{1n}^{k} \\ \tilde{d}_{21}^{k} & \dots & \dots & \tilde{d}_{2n}^{k} \\ \dots & \dots & \dots & \dots \\ \tilde{d}_{n1}^{k} & \tilde{d}_{n2}^{k} & \dots & \tilde{d}_{nn}^{k} \end{bmatrix} \quad (2.5)$$

Step 2: If there is more than one decision maker, preferences of each decision maker ($\tilde{d}_{ij}^{k}$) are averaged and ($\tilde{d}_{ij}$) is calculated as in the Eq. 7

$$\tilde{d}_{ij} = \frac{\sum_{k=1}^{K} \tilde{d}_{ij}^{k}}{K} \quad (2.6)$$

Step 3: According to averaged preferences, pair wise contribution matrices is updated as shown in Eq. 8

$$\widetilde{A} = \begin{bmatrix} \tilde{d}_{11} & \cdots & \tilde{d}_{n1} \\ \vdots & \ddots & \vdots \\ \tilde{d}_{1n} & \cdots & \tilde{d}_{nn} \end{bmatrix} (2.7)$$

Step 4: According to Buckley (1985), the geometric mean of fuzzy comparison values of each criterion is calculated as shown in Eq. 9. Here, still represents triangular values

$$\widetilde{r_i} = \left(\prod_{j=1}^{n} \widetilde{d_{ij}}\right)1/2, \qquad \text{i=1, 2, 3….n} \qquad (2.8)$$

Step 5: The fuzzy weights of each criterion can be found with Eq. 2.9, by incorporating next 3 sub steps.

Step 5a: Find the vector summation of each$\widetilde{r_i}$.

Step 5b: Find the (-1) power of summation vector. Replace the fuzzy triangular number, to make it in an increasing order.

Step 5c: To find the fuzzy weight of criterion i ($\widetilde{w_i}$), multiply each ($\widetilde{r_i}$) with this reverse vector.

$$\widetilde{w_i} = \widetilde{r_i} * (\widetilde{r_1} \oplus \widetilde{r_2} \oplus \ldots \oplus \widetilde{r_n}) exp - 1 \qquad (2.9)$$

$$= (lw_i\ , mw_i, uw_i)(2.10)$$

Step 6: Since $\widetilde{w_i}$ are still fuzzy triangular numbers, they need to de-fuzzified by Centre of area method proposed by Chou and Chang (2008), via applying the equation 12.

$$M_i = \frac{lw_i + mw_i + uw_i}{3}(2.11)$$

Step 7: M_i is a non fuzzy number. But it needs to be normalized by following Eq. 13

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i}(2.12)$$

These 7 steps are performed to find the normalized weights of both criteria and the alternatives.

Then by multiplying each alternative weight with related criteria, the scores for each alternative is calculated. According to these results, the alternative with the highest score is suggested to the decision makers.

The MADM methods explained in above sections have their own strong and weak side and they are suitable for different cases.

This particular paper was applied the above steps for selection potential facility location to establish a regional warehouses from which the product distributed within study area.

2.4. Literatures related to distribution network design practices

Some researchers have looked at facility location problems as independent decision issues (e.g., Aikens, 1985; Owen and Daskin, 1998; Bhutta, 2004; Wu et al., 2006; Sahin and Sural, 2007; Rentizelas and Tatsiopoulos, 2010). There have been many attempts to solve facility location problem along with other decision issues such as allocation (e.g., Ohlemuller, 1997; Murat et al., 2010), allocation and routing(e.g., Wu et al., 2002; Lashine et al., 2006; Nagy and Salhi, 2007), transportation and inventory (e.g., Jayaraman, 1998; Perl and Sirisoponslip, 1988; Shen and Qi, 2007),inventory control (e.g., Ballou, 1984; Miranda and Garrido, 2006; Wang et al., 2007;Gebgennini et al., 2009), storage capacity calculation (e.g., Levén et al., 2004) and supply chain management (e.g., Tsiakisa and Papageorgiou, 2008; Melo et al., 2009).Furthermore, in the last decade, the facility location problem as an integral problem while designing a distribution network has attracted the attention of researchers and these types of researchers are closely related to the problem addressed in this study.

To review some of closely related literatures to this particular study:

Chopra (2003) described a framework for designing the distribution network in a supply chain by considering various factors such as response time, product variety, product availability, customer experience, order visibility and return ability influencing the choice of distribution network.

Kuekkong (2011) presented the location decisions in distribution network design to enable answer the question of company when they intend to increase capacity of facilities such as how many distribution centers should be located, where the distribution centers should be located and what size each distribution center should be. The study was done by setting baseline network scenarios and implemented COG method and LOGWARE program to decide the location of the warehouses.

Klose and Drexl (2005) classified the facility location models for distribution systems design. They also reviewed some of the contributions and summarized the continuous locations models, network location models, mixed-integer programming models and applications in an effective way.

Avittathur et al. (2003) studied the effect of CST rates and product variety on Distribution Centre (DC) locations and concluded that CST has an effect. They developed a non-linear mixed-integer programming model with an objective function of minimizing total cost to determine DC locations considering the impact of CST.

Amiri (2006) studied the problem of designing a distribution network in a supply chain system that involves determining simultaneously the best locations of both plants and warehouses and best policy for distributing the product from the plants to warehouses and from the warehouses to the customers. The researcher proposed mathematical model by considering the traditional costs associated with facility location and distribution problems such as variable cost due to supplying the products from plant to warehouses as well as from warehouses to customers and fixed cost due to opening and operating warehouse with specific capacity level. Also, proposed heuristic solution procedure based on Lagrangian relaxation of the problem and demonstrated the quality of the proposed heuristic algorithms by conducting suitable computational experiments.

Bidhandi et al. (2009) proposed a new approach for determining supply chain network design considering simultaneously the strategic decisions concerning facilities selection with the tactical decisions concerning supplier, production, warehouse and customer allocation, the facility location and allocation problem. They proposed a Mixed-Integer Linear Programming (MILP) model with (0–1) variables. Because of the computational difficulties, they proposed a modified version of Benders' decomposition to solve MILP model with (0–1) variables and following this they developed a new algorithm based on the surrogate constraints.

However, Hanna et al. (1993) used breakeven analysis to modern production economics while modeling economies of scale and economies of scope. They found traditional cost benefit analysis inadequate in their context of study and suggested a modified cost-volume-flexibility breakeven analysis for their study.

2.5. Literature gap

Some of literatures mentioned above like by Amiri (2006), Klose and Drexl (2005) and Bidhandi et al. (2009) considered facility location and distribution network as integral issue and models developed to locate facilities for both the distribution centers and plants simultaneously with designing a distribution network.

But this particular study intended to design a network design for a company that already decided the location of plant but not the distribution centers. The study located a facility for regional distribution centers as independent issue by applying one MADM methods FAHP prior to designing of distribution network.

Even though there are many papers and articles done on a designing of distribution networks, there is not much done regarding a distribution network design of bottled water products and the study tried to fill the gap in the area.

In Ethiopia, as it can be seen in the above literatures, the distribution network designing and implementing practices did not get much attention of many researchers and this particular paper tries to fill the literature gap of distribution network design in Ethiopia.

This study was done by applying transshipment model to calculate the optimal cost of distribution and to allocate the warehouses to demand locations and FAHP was used decide regional warehouse locations in study region.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1.Introduction

This chapter presents mainly the methods were applied, materials and tools were used to achieve the objective of the study, which is to design a distribution network that minimizes cost and identify the associated causes and impacts of not meeting target customer. Beside this, the chapter also presents the description of the study area and study subject, validity and reliability of the study, and researcher's ethical considerations.

3.2.Description of the Study Area

Figure 3.1: SNRS location map (Source: Google map)

The research project was carried out in SNRS which is found in Ethiopia, on the shores of Lake Hawassa in the Great Rift Valley. It is located 273 km (81mi) south of Addis Ababa. The state is newly established. It lies on the Trans-African Highway from Cairo-Cape Town and has a latitude and longitude of $7^{o}3$'N $38^{o}28$'E and an elevation of 1,708 meters (5,604ft) above sea level.

3.3.Study Subject

The study subject of this research were South Spring Water distributers, Retail shop owners and the manufacturer of South Spring Water, Garamba Bottling. The business type of the study subject is manufacturing and distribution of bottled water for customers. The retail shops and distribution centers which were open during data collection was studied.

3.4.Research design

This research project intended to randomly select one retail shop in 15 Demand points depending on size and demand of the Demand points and two shops in 18 Demand points and 10 retail shops in Hawassa city(who represent respective retail shops) from each Demand points.

Sampling Technique: for this research study, the researcher selected probability simple random sampling technique to select from retailers of SPW water in SNRS and from the company officials to conduct an interview to collect information necessary for further analysis.

Sample Size: For this research study, because of impossibility to get information from all retailers and customers included in the study population due to time and cost constraints, sample was taken in order to have a size that would be representative of whole population being studied. The sampling frame was the water distributors or regional agents and the company Garamba Bottling.

The design of the research is summarized in figure 3.2 which is the flow diagram of the design of this particular research.

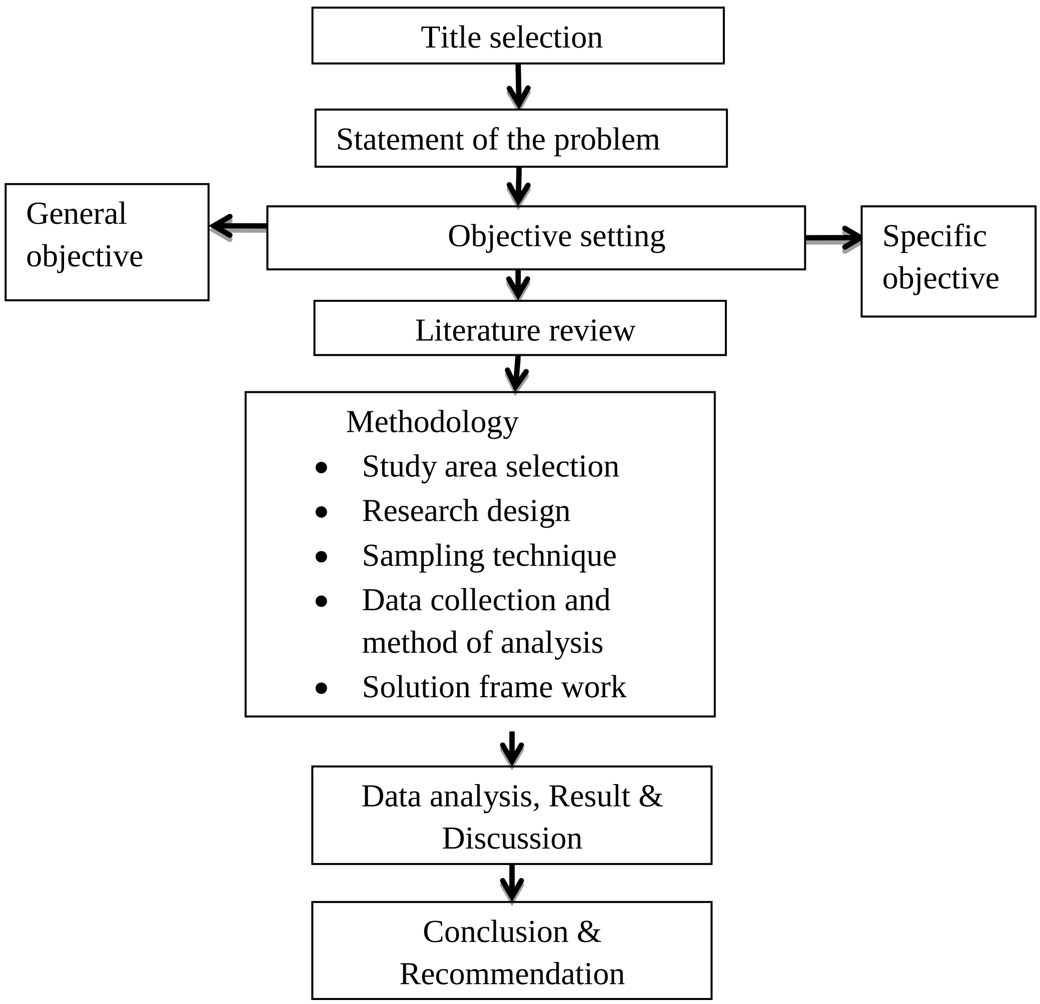


Figure3.2: Research design flow diagram (Source: Researcher)

3.5.Research Approach

The research followed, mixed approach, quantitative and qualitative approach. In qualitative approach regarding this specific case, the research aimed to gather in-depth information about the way the company product, SPW, is being distributed with in SNPR and the distribution network design practices in water bottling companies and also to understand the cost factors related to transportation and distribution of SPW. The researcher used this information to formulate the solution methods for minimization of cost of transportation.

In quantitative approach, the data's collected for further analysis is analyzed like transportation cost modeling, facility location selection, decision regarding number of distribution centers and location decided based on quantitative analysis.

3.6.Data Collection Procedure

To find answers to a research study question or problem it is important to collect data from relevant sources. There are two types of data based their source. These are primary data and secondary data. Both data types were used for this research study.

3.6.1. Secondary Data

Before primary data construction, it is compulsory for researcher knowing past knowledge under the research objectives. This can be done through secondary data discussion. For this research study, secondary data were gathered through selecting and reviewing books, journals, thesis, dissertations and internet source articles that are related to the research study. Review of the company documents provided date about past experiences, which related to a distribution network design. Therefore, it gave a big ground to this research study.

3.6.2. Primary Data

For this study, observation and personal interview primary data collection methods have been used. Through observation the way the company, Garamba Bottling, distributing its product was observed in depth and also the network being implemented by the company to distribute the product within study area was observed.

The interview of data collection is very useful in extensive enquiries and can lead to fairly reliable results (Kothari, 2004). For these advantages, the researcher has prepared interview questions to get information about the customer experience and distribution practice of the company (Garamba Bottling).

The information about the company was gained from company officials who are directly related to the issue under study, like warehouse manager, distribution and sells department managers were interviewed and about the whole distribution practice within region from water distributer or retail shop owners and agents.

3.7.Solution frame work

In this section, the solution framework for the problem discussed is presented.

The problem addressed in this study is viewed as the two-stage decision problem, namely (1) decision on warehouse location, and (2) designing a new cost effective distribution network by improving the existing distribution network of the company.

1. First stage of solution frame work

In the first stage of solution like mentioned earlier the decision about where to locate a new warehouse facility that serve the purpose of the regional distribution centers was made. To do so, the fuzzy AHP is the best option among the options discussed under literature review section.

Steps discussed under literature section about FAHP were applied to select the best location for warehouse facility from candidate locations. The candidate locations were selected from study area by the researcher by using some heuristic approach.

After the locations for warehouse selected the second stage of the solution frame was analyzed

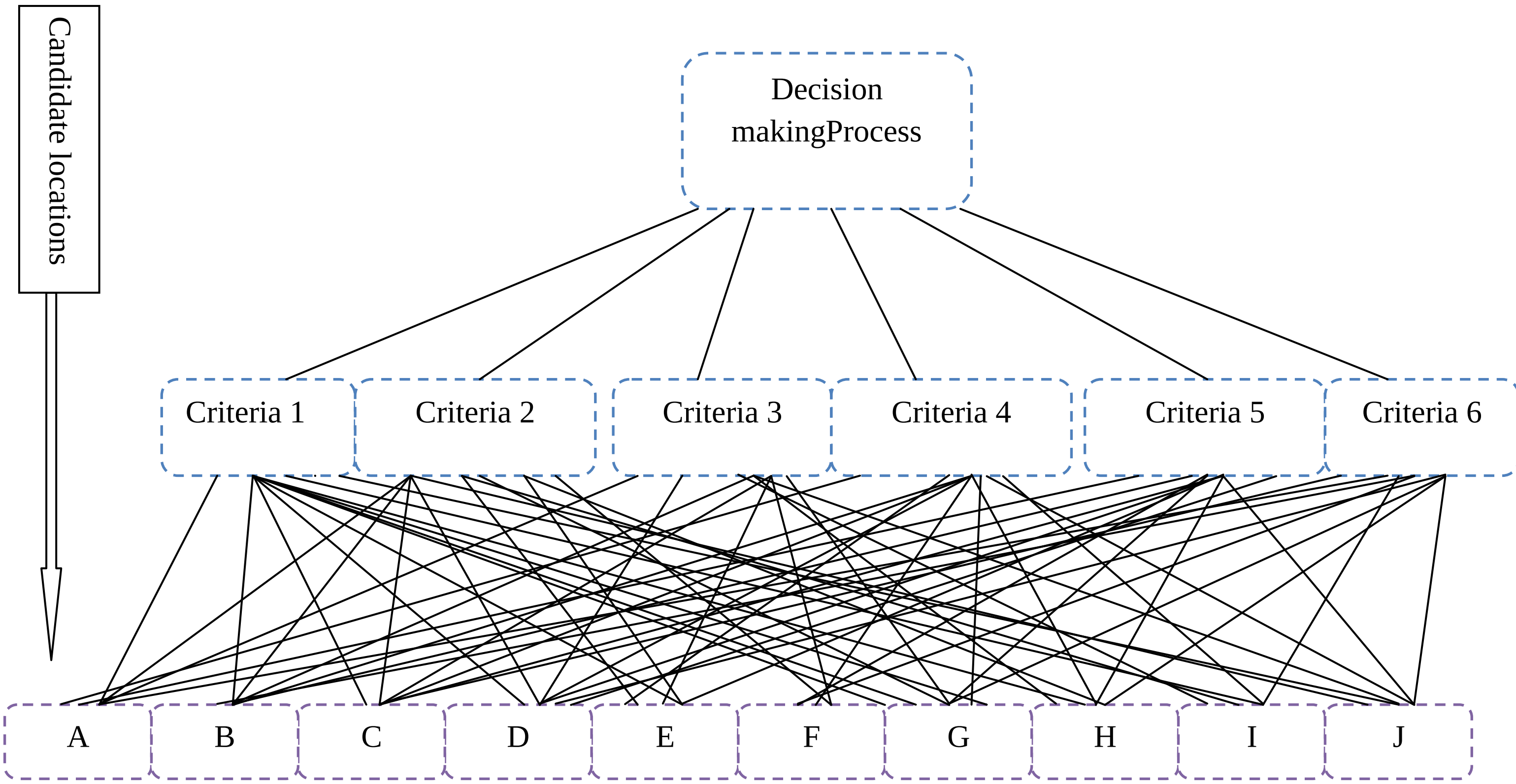


Figure 3.3: Location decision making process of the case study (Source: Researcher)

2. Second stage of solution frame work

The second stage of the solution frame was designing the cost effective distribution network for the case company by integrating the warehouses selected at first stage of the solution frame into the existing distribution network.

As discussed under literature review section the problem is transshipment problem and the transshipment model discusses was implemented to calculate the optimal cost of distribution and to allocate warehouses to demand areas within SNRS.

3.8.Method of Data Analysis

It is important for research to adopt appropriate techniques of data analysis in order to get objective results (Blaxter et al., 2006). Two types of primary data were collected, the qualitative and quantitative data. Hence, this research employs both quantitative and qualitative data analysis methods to improve the reliability the research results.

3.8.1. Quantitative Data Analysis

The procedures and models that will be implemented to select the regional warehouse locations, a unit transportation cost and the transportation cost minimization transshipment model are presented as follows:

The regional distribution center location was found by using FAHP and four locations that ranked from one to four were selected to establish new regional distribution center of the company. The number of the regional distribution center is decided from the investment plan information that was given by the company officials. Like they said the company has a plan to construct additional three regional distribution centers in addition to the one already in function which is located in Hawassa.

The FAHP was solved with the help Microsoft excel software tool.

3.8.2. Qualitative Data Analysis

Qualitative data was gathered from key informants (Financial Manager, General Manager, and Warehouse Manager) through interviews then organized and categorized thematically and written up into narratives. The narrative followed by analysis and interpretation.

The qualitative date analysis was mainly employed by the researcher to select list of candidate locations to establish the potential ware houses.

The cost of transportation before and after the new distribution network designed was compared. The cost of transportation before the new distribution network was developed was taken from the company and it was compared to newly calculated cost and the result was concluded.

3.9.Ethical Consideration

Before undertaking any study involving human participants, it is necessary to a researcher to consider researching ethical principles. These are informing respondents about objective and purpose of research study, respecting rights and privacy of respondents, obeying willingness of respondents, acknowledging all the works of others used in study. According to Yin. (2014)adherence to ethical principles by researchers will add credibility to the study. Thus the researcher conducted the research study in considering the ethical principles.

CHAPTER FOUR: RESULT AND ANALYSIS

4.1. Existing destinations of the company products within the region

The company has many destinations in the region and the CDCs are in Addis Ababa, Modjo, Hawassa city and Della from which the product will be distributed to different regions within the country through agent and the company sells.

Yet this research is intended to design a distribution network only in SNRS due to research limitations mentioned in chapter one of this research papers and the rest of the country will be studied by another researcher or another time.

The product from the factory is being shipped to only five locations, which are RDCs of the agent, within a region which are: - Hawassa, Bensa Daye, AletaWondo, Bona and Hagereselam. These are places where the agent of the company has sub agents which will distribute the product to the local market and to some neighboring Demand points' in the region depending on demand and the knowledge of the subagent about the area.

There is a proper warehouse only in Hawassa city, the rest of the above destinations do not have proper warehouse the store the product.

The company implements both agent and its own sales for the distribution of the product in the region. Most of the areas in the region are being supplied through agent who is located at Hawassa city Mr. Aschalew, the only agent of the company. The agent have its own sub agents located at Bensa, Bona, Aleta, and Hagereselam whom will receive the product from the company under the main agent order and then distributes them to their customers.

Based on the information from the subagents, they were selected randomly and in a favor of the main agent Mr. Aschalew but there was no research or any logistic related criteria for assigning and selecting the sub agents in the region.

The company also has its own sales and ware house in Hawassa city which distributes the product to different retail shops, hotels, and customers in Hawassa city and to neighboring Demand points' to the city like Wondogenet, Leku, Dore and so on.

4.1.2. The demand and the demand areas in the region

Currently bottled water is being drunk in all Demand points' of SNRS. As the researcher noticed during his travel to different Demand points' within a region, majority of consumers has tested the product SPW. But they complained highly about its availability in the market.

The demand areas in the region are all of the Demand points' in the region and those districts and villages are included within a Demand points'.

The Demand points or possible destinations for a product within SNRS are listed below with their respective representation:-

A=BensaDaayye	K=Arooreessa	U= Gorche
B=Aletawondo	L=Xexicha	V=Baleela
C=Cirre	M=Girja	W=Shafaamo
D=Hagere selam	N=Ganbelto	X=Doore
E=Lekku	O=Cabbe	Y=Shaamanna
F=Boona	P=Burra	Z=Wonsho
G=Hawaasa	Q=Bursa	a=Daraara
H=Yirgalem	R.=Wondogenet	b=Malga

I=YirbaBoricha	S=Cirone	c=Lokka Abaya
J=Daarra	T=Haweela	d=Cuukko
e=Daeela	f= Guguma	

4.1.3. The Existing distribution network

Currently the product is being supplied to five major Demand points' directly from the factory based on pre placed order. Then from those locations the product will be sold to consumers within that woreda and some neighboring Demand points' through retailers.

The current distribution network can be represented as shown in figure 2 below.

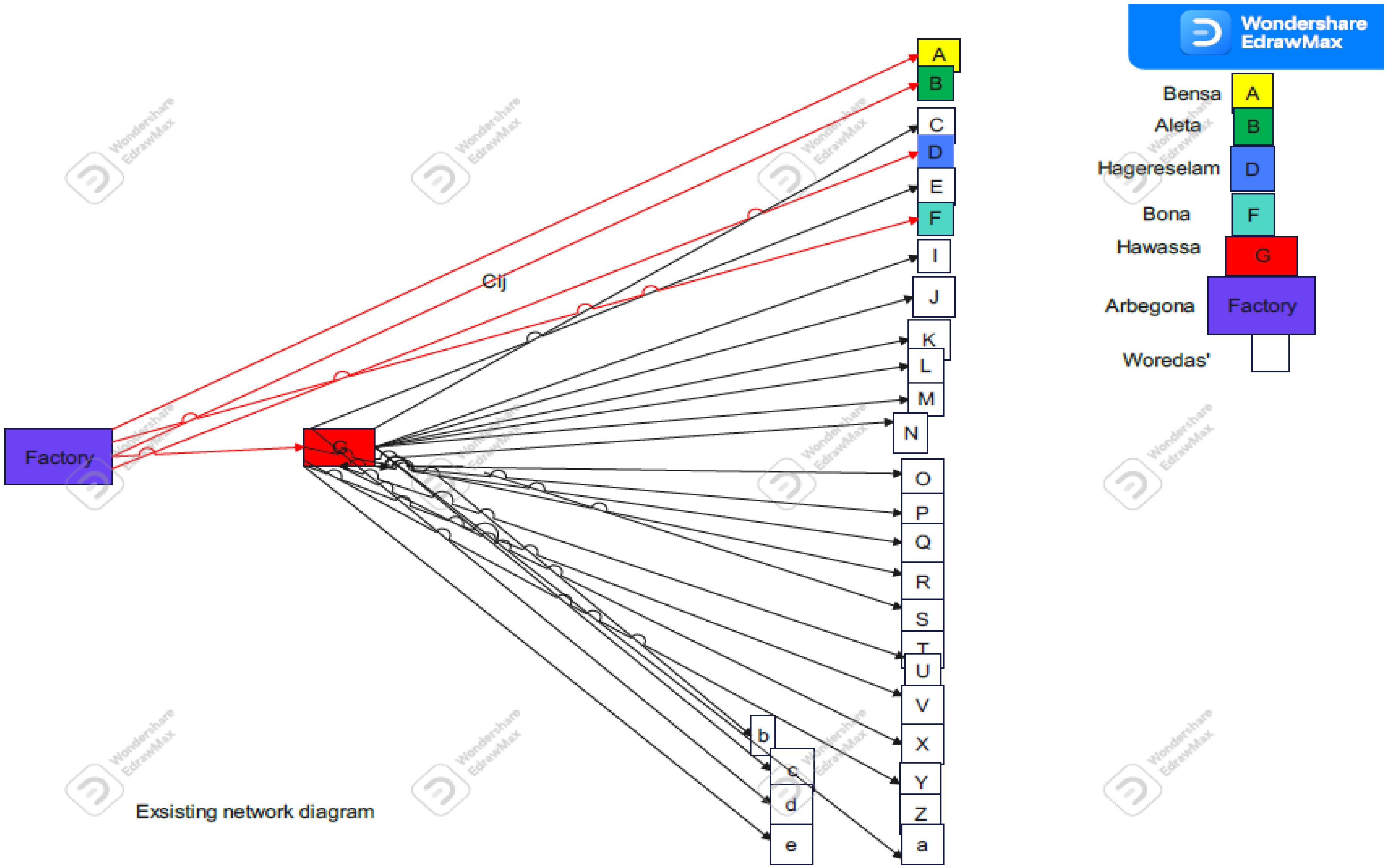


Figure 2: Existing distribution network of the company

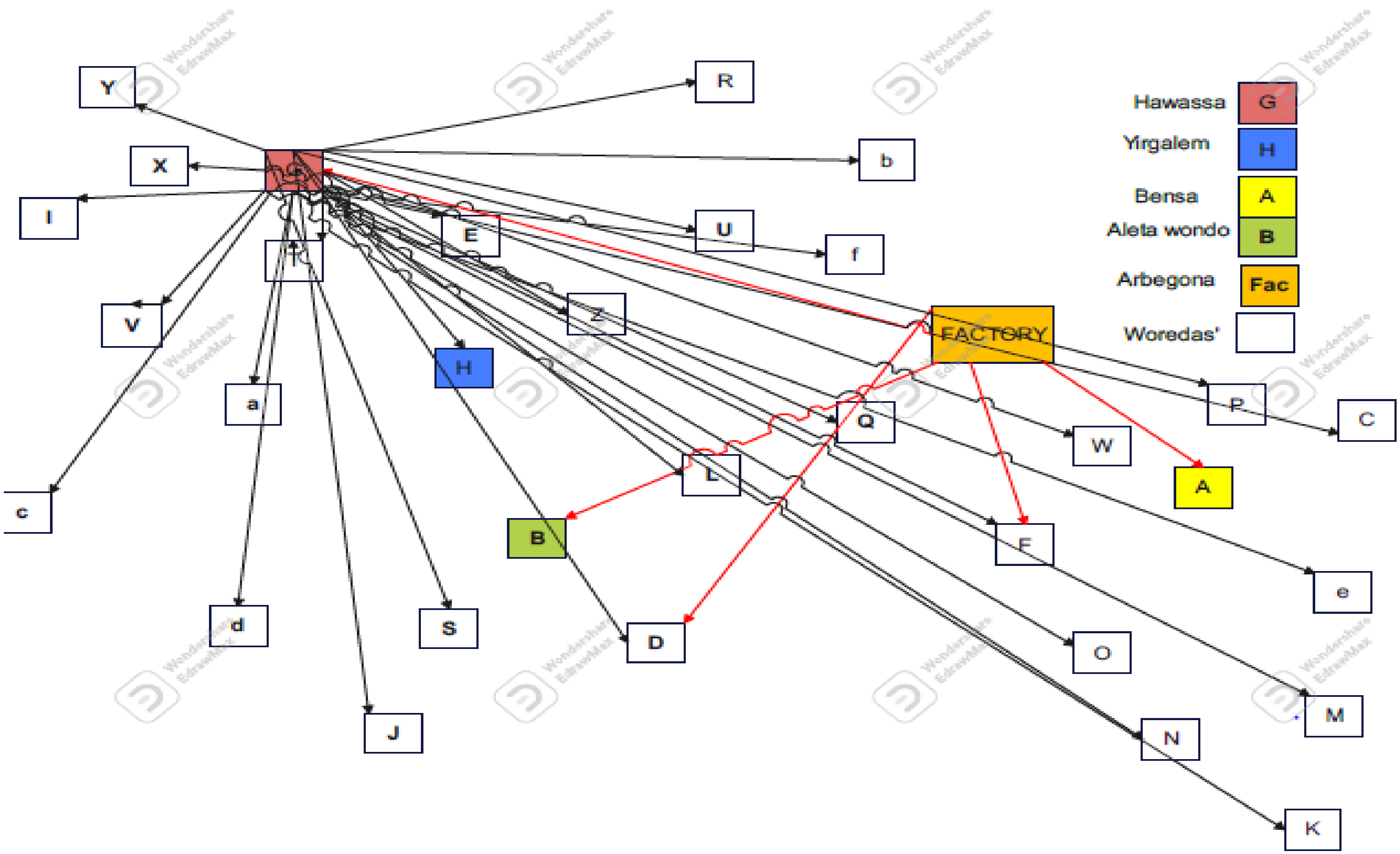


Figure 3: Existing distribution network of the company with respect to its geographical locations

Table 4.1: Demand data of different Demand points' (Source: Garamba Bottling)

Demand	Demand of different size bottle per packs per week			
	0.6l	1.2l	2l	Total Demand
A. Bensa	2500	3500	2500	11000
B. Aleta wondo	3500	5000	4000	16500
C. Cirre	1000	2000	1050	5100
D. Hagere selam	1000	1800	1250	5300
E. Lekku	1400	2000	1050	5500
F. Boona	1000	1800	1250	5300
G. Hawassa	15000	20000	8000	51000
H. Yirgalem	3500	5000	4000	16500
I. Boricha	400	1000	500	2400
J. Daarra	1400	2000	1050	5500
K. Arooreessa	1000	1800	1250	5300
L. Xexicha	250	600	400	1650
M. Girja	1400	2000	1050	5500
N. Ganbelto	250	600	400	1650
O. Cabbe	400	1000	500	2400
P. Burra	250	600	400	1650
Q. Bursa	1000	1800	1250	5300
R. Wondogenet	1400	2000	1050	5500
S. Cirone	250	600	400	1650

T. Haweela	400	1000	500	2400
U. Gorche	250	600	400	1650
V. Baleela	400	1000	500	2400
W. Shafaamo	250	600	400	1650
X. Doore	400	1000	500	2400
Y. Shaamanna	400	1000	500	2400
Z. Wonsho	400	1000	500	2400
a. Daraara	400	1000	500	2400
b. Malga	1000	1800	1250	5300
c. Lokka Abaya	400	1000	500	2400
d. Cuukko	1400	2000	1050	5500
e. Daeela	400	1000	500	2400
f. Guguma	250	600	400	1650
Total weekly demand	**2,275,800packs/week**			

The demand of each Demand points above was taken by reviewing the company sales record of year 2012 E.C. The packaging is, for 0.6l, 12 pieces are considered as one pack, for 1.2l, 6 pieces are considered as one pack and for 2l, 6 are pieces as one pack.

4.1.5. The Total transportation cost to the current destinations

Assumption: - the main thing assumed here is that, road characteristic which is assumed to be asphalt. Since almost all of the roads connecting Demand points to Demand points are asphalt and those of which are not are under construction. And also 1.2l size bottle will be used throughout the analysis.

Based information taken from reviewing company documents and company officials the company is currently renting the vehicle to transport a product from the factory (Arbegona) to Hawassa, which is 77km; the company is paying/ renting trailer truck by 23,000 birr/trip.

And the capacity of the vehicle when loaded fully is 420 quintal, equivalent to 5100 packs of 1200ml bottle, is currently being shipped by the company.

If 5100packs=2300birr

12 =X

Then X=54.18birr/ 12pack or 4.51birr/pack

Since 12 packs is equivalent to 1 quintal so the company is paying 54.18birr/quintal/ 77km

Then from:

54.18birr=77km

X=1km

Therefore the current unit transportation cost of the company is 0.70birr/quintal/km or 0.70 birr/12pack/km or **0.058birr**/pack/km

And from this the existing transportation cost can be found by assuming all the Demand points in the region is getting the product not directly from the company but through the agent who has its warehouse in Hawassa city.

Table4.2: Existing distribution cost to each destination (Source: Garamba Bottling)

	Through	To	Distance in km	Demand per week	Unit cost of transport	Total cost of transport
Factory	-	Bensa	25	11000	0.058birr	15950birr
Factory	-	Aletawondo	71	16500	0.058birr	67947birr
Factory	Hawassa	Cirre	277	5100	0.058birr	81936.60birr
Factory	-	Hagere selam	70	5300	0.058birr	21515birr
Factory	Hawassa	Lekku	101	5500	0.058birr	32219birr
Factory	Hawassa	Boona	20	5300	0.058birr	6148birr
Factory	-	Hawassa	77	51000	0.058birr	227766birr
Factory	Hawassa	Yirgalem	120	16500	0.058birr	114840birr
Factory	Hawassa	Boricha	106	2400	0.058birr	14755.20birr
Factory	Hawassa	Daarra	161	5500	0.058birr	51359birr
Factory	Hawassa	Arooreessa	253	5300	0.058birr	77772.20birr
Factory	Hawassa	Xexicha	161	1650	0.058birr	15407.70birr
Factory	Hawassa	Girja	246	5500	0.058birr	78474birr
Factory	Hawassa	Ganbelto	243	1650	0.058birr	23255.10birr
Factory	Hawassa	Cabbe	233	2400	0.058birr	32433.60birr
Factory	Hawassa	Burra	251	1650	0.058birr	24020.70birr
Factory	Hawassa	Bursa	174	5300	0.058birr	53487.60birr
Factory	Hawassa	Wondogenet	97	5500	0.058birr	30943birr
Factory	Hawassa	Cirone	183	1650	0.058birr	17513.10birr

Factory	Hawassa	Haweela	89	2400	0.058birr	12388.80birr
Factory	Hawassa	Gorche	114	1650	0.058birr	10909.80
Factory	Hawassa	Baleela	122	2400	0.058birr	16982.40birr
Factory	Hawassa	Shafaamo	198	1650	0.058birr	18948.60birr
Factory	Hawassa	Doore	101	2400	0.058birr	14059.20birr
Factory	Hawassa	Shaamanna	112	2400	0.058birr	15590.40birr
Factory	Hawassa	Wonsho	133	2400	0.058birr	18513.60birr
Factory	Hawassa	Daraara	133	2400	0.058birr	18513.60birr
Factory	Hawassa	Malga	101	5300	0.058birr	31047.40birr
Factory	Hawassa	Lokka Abaya	131	2400	0.058birr	18235.20birr
Factory	Hawassa	Cuukko	137	5500	0.058birr	43703birr
Factory	Hawassa	Daeela	243	2400	0.058birr	33825.60birr
Factory	Hawassa	Guguma	121	1650	0.058birr	11579.50birr
Grand total	**1,252,039.90 birr/week**					

From above table it can be seen that the existing total transportation cost for supplying SNRS is **1,252,039.90birr/week**

4.2. Calculating optimal distribution costs

Here the total minimized cost of distribution is calculated by identifying best locations for the warehouses with help FAHP and by applying the transshipment model to the problem.

4.4.1. Possible warehouse locations for the company

Possible warehouse locations are locations in which warehouse facility can be built. These locations could be one of Demand points in the region.

Here are list of candidate Demand points and city administrations for establishing potential regional warehouse to meet demand of the customers within a region.

- ✓ Bensa Daayye
- ✓ Aleta wondo
- ✓ Cirre
- ✓ Hagere selam
- ✓ Lekku
- ✓ Boona
- ✓ Hawassa
- ✓ Yirgalem
- ✓ Cuukko
- ✓ Daarra

4.2.2. Selecting from a candidate ware houses by using the FAHP

Based on information from the investment plan and demand information taken from the company officials, four distribution centers or warehouses can meet the demand of target customer including the one in play which is located in Hawassa.

To select these four locations from list of candidates FAHP is suitable. To do so Pair wise comparison and weight calculation will be adapted.

The FAHP is a very popular, subjective-decision making tool that is relatively easy to use. It consists of these steps:

Fuzzy Analytical Hierarchy Process

AHP is one of the well-known multi-criteria decision making (MCDM) technique developed by Thomas Saaty. FAHP methodology has following

Step1. Identify the problem and define the criteria.

Step2. Construct the hierarchy of the decision problem based on the aim of the decision.

Step3. Structure comparison matrix by using experts' judgments

Step4. Find local or global weights and priorities

Step5. Calculate consistency index (CI) and consistency ratio (CR)

Step6. Check if CR value is less than 0.10 (comparisons is appropriate)or not.

As we can see in above steps there is a different factor that must be considered to implement the technique chosen to select the facility location.

After investigating each and every step one by one, the required four facility location will be selected from list possible candidates' based on their weight calculation done by experts' judgment.

Step1. Identify the problem and define the criteria.

Here are list of important factor for this particular case from factors affecting location decision heuristically selected by the group of experts in particular area are:

Table 4.3: location selecting criteria and their representation

Selecting criteria	Its representation
Cost and availability of energy/ utilities	1
Business climate	2
Proximity to customer	3
Weather	4
Cost availability, skill and productivity of labor	5
Construction costs and land price	6

Step2. Construct the hierarchy of the decision problem based on the aim of the decision

The pair wise comparison matrix table for decision parameters is

Table 4.4: Relative value vector matrix Table (Source: group of experts)

	1			2			3			4			5			6		
1	1	1	1	1/3	1/2	1	1/6	1/5	1/4	1	1	1	4	5	6	1	2	3
2	1	2	3	1	1	1	1/3	1/2	1	1	2	3	4	5	6	4	5	6
3	4	5	6	1	2	3	1	1	1	4	5	6	7	8	9	7	8	9
4	1	1	1	1/3	1/2	1	1/6	1/5	1/4	1	1	1	4	5	6	1	2	3
5	1/6	1/5	1/4	1/6	1/5	1/4	1/9	1/8	1/7	1/6	1/5	1/4	1	1	1	1/3	1/2	1
6	1/3	1/2	1	1/6	1/5	1/4	1/9	1/8	1/7	1/3	1/2	1	1	2	3	1	1	1

Result from the weight calculation that done by excel is

Eigen vectors are: 1=0.119, 2=0.205, 3=0.471, 4=0.119, 5=0.031, 6=0.055 these are also called RVV (relative value vectors).

These results shows that the company values proximity to the customer most of all the parameters and the business environment follows

$\Lambda max=6.170$, CI=0.034

From corresponding values from large samples of matrices of purely random judgments' for n=6 is 1.24

Then CR=CI/1.24

CR=0.027<0.1 safe or consistent

Step3. Structure comparison matrix by using experts' judgments

Criteria 1 (cost, availability of energy and utilities) candidate locations pair wise comparison matrix

Table 4.5: Pair wise comparison matrix for selection criteria1 (Source: group of experts)

	A			B			C			D			E			F			G			H			I			J		
A	1	1	1	1/3	1/2	1	1	2	3	1	2	3	1	2	3	1	2	3	1/6	1/5	1/4	1/3	1/2	1	1	1	1	1	2	3
B	1	2	3	1	1	1	1	1	1	1	2	3	1	2	3	1	2	3	1/3	1/2	1	1/3	1/2	1	1	1	1	1	2	3
C	1/3	1/2	1	1/3	1/2	1	1	1	1	1	1	1	1/3	1/2	1	1	1	1	1/6	1/5	1/4	1/6	1/5	1/4	1/3	1/2	1	1	1	1
D	1/3	1/2	1	1/3	1/2	1	1	1	1	1	1	1	1	1	1	1	1	1	1/6	1/5	1/4	1/6	1/5	1/4	1/3	1/2	1	1	1	1
E	1/3	1/2	1	1/3	1/2	1	1	2	3	1	1	1	1	1	1	1/3	1/2	1	1/6	1/5	1/4	1/6	1/5	1/4	1	1	1	1/3	1/2	1
F	1/3	1/2	1	1/3	1/2	1	1	1	1	1	1	1	1	2	3	1	1	1	1/6	1/5	1/4	1/6	1/5	1/4	1/3	1/2	1	1	1	1
G	4	5	6	1	2	3	4	5	6	4	5	6	4	5	6	4	5	6	1	1	1	1	2	3	4	5	6	4	5	6
H	1	2	3	1	1	1	4	5	6	4	5	6	1	2	3	4	5	6	1/3	1/2	1	1	1	1	1	2	3	1	2	3
I	1	1	1	1/3	1/2	1	1	2	3	1	2	3	1	1	1	1	2	3	1/6	1/5	1/4	1/3	1/2	1	1	1	1	1	2	3
J	1/3	1/2	1	1/3	1/2	1	1	1	1	1	1	1	1	2	3	1	1	1	1/6	1/5	1/4	1/3	1/2	1	1/3	1/2	1	1	1	1

Result from the weight calculation that done by excel is

Eigen vectors are: A=0.085027, B=0.141277, C=0.041088, D=0.04586, E=0.047198, F=0.047198,G=0.302420, H=0.1576545, I=0.082616, J=0.049672

Λmax=10.2856

CI=0.0317

From corresponding values from large samples of matrices of purely random judgments' for n=10 is 1.49

Then CR=CI/1.49

CR=0.0213<0.1 safe or consistent

Candidate location solution matrix based on each decision parameter

Criteria2 (Business climate) candidate locations pair wise comparison matrix

Table 4.6: Pair wise comparison matrix for selection criteria 2(Source: group of experts)

		A			B			C			D			E			F			G			H			I			J	
A	1	1	1	1/3	1/2	1	1	2	3	1	2	3	1	2	3	1	2	3	1/6	1/5	1/4	1/3	1/2	1	1	2	3	1	2	3
B	1	2	3	1	1	1	4	5	6	4	5	6	1	2	3	4	5	6	1/3	1/2	1	1	2	3	1	2	3	1	2	3
C	1/3	1/2	1	1/3	1/2	1	1	1	1	1	2	3	1	1	1	1	1	1	1/9	1/8	1/7	1/3	1/2	1	1	1	1	1	2	3
D	1/3	1/2	1	1/6	1/5	4	1	1	1	1	1	1	1/3	1/2	1	1/3	1/2	1	1/9	1/8	1/7	1/6	1/5	1/4	1/6	1/5	1/4	1	1	1
E	1/3	1/2	1	1/3	1/2	1	1	1	1	1	2	3	1	1	1	1/3	1/2	1	1/9	1/8	1/7	1/3	1/2	1	1	1	1	1	2	3
F	1/3	1/2	1	1/6	1/5	1/4	1	1	1	1	2	3	1	2	3	1	1	1	1/9	1/8	1/7	1/3	1/2	1	1	1	1	1	2	3
G	4	5	6	1	2	3	7	8	9	7	8	9	7	8	9	7	8	9	1	1	1	4	5	6	7	8	9	7	8	9
H	1	2	3	1/3	1/2	1	1	2	3	4	5	6	1	2	3	1	2	3	1/6	1/5	1/4	1	1	1	1	2	3	4	5	6
I	1/3	1/2	1	1/3	1/2	1	1	1	1	4	5	6	1	1	1	1	1	1	1/6	1/5	1/4	1/3	1/2	1	1	1	1	1	2	3
J	1/3	1/2	1	1/3	1/2	1	1/3	1/2	1	1	1	1	1	1	1	1/3	1/2	1	1/9	1/8	1/7	1/6	1/5	1/4	1/4	1/3	1/2	1	1	1

Result from the weight calculation that done by excel is

Eigen vectors are: A=0.09205 B=0.14086, C=0.05573, D=0.02626, E=0.04008, F=0.05139,

G=0.37187, H=0.12420, I=0.06066, J=0.03690

Λ max=10.517

CI=0.0575

From corresponding values from large samples of matrices of purely random judgments' for n=10 is 1.49

Then CR=CI/1.49

CR=0.0386<0.1 safe or consistent

Criteria 3(proximity to market) candidate locations pair wise comparison matrix

Table 4.7: Pair wise comparison matrix for selection criteria 3(Source: group of experts)

	A			B			C			D			E			F			G			H			I			J		
A	1	1	1	1	1	1	4	5	6	4	5	6	4	5	6	4	5	6	1/3	1/2	1	1	1	1	1	2	3	4	5	6
B	1	1	1	1	1	1	4	5	6	4	5	6	4	5	6	4	5	6	1/3	1/2	1	1	2	3	1	2	3	4	5	6
C	1/6	1/5	1/4	1/6	1/5	1/4	1	1	1	1	1	1	1/3	1/2	1	1/3	1/2	1	1/9	1/8	1/7	1/6	1/5	1/4	1/6	1/5	1/4	1	1	1
D	1/6	1/5	1/4	1/6	1/5	1/4	1	1	1	1	1	1	1/3	1/2	1	1/3	1/2	1	1/6	1/5	1/4	1/3	1/2	1	1	2	3	1	2	3
E	1/6	1/5	1/4	1/6	1/5	1/4	1	2	3	1	2	3	1	1	1	1	1	1	1/6	1/5	1/4	1/3	1/2	1	1	2	3	1	2	3
F	1/6	1/5	1/6	1/6	1/5	1/4	1	2	3	1	2	3	1	1	1	1	1	1	1/6	1/5	1/4	1/3	1/2	1	1	1	1	1	2	3
G	1	2	3	1	2	3	7	8	9	4	5	6	4	5	6	4	5	6	1	1	1	4	5	6	4	5	6	7	8	9
H	1	1	1	1/3	1/2	1	4	5	6	1	2	3	1	2	3	1	2	3	1/6	1/5	1/4	1	1	1	1	1	1	1	2	3
I	1/3	1/2	1	1/3	1/2	1	4	5	6	1	2	3	1/3	1/2	1	1	1	1	1/6	1/5	1/4	1	1	1	1	1	1	1	2	3
J	1/6	1/5	1/4	1/6	1/5	1/4	1	1	1	1	1	1	1/3	1/2	1	1/3	1/2	1	1/9	1/8	1/7	1/3	1/2	1	1/4	1/3	1/2	1	1	1

Result from the weight calculation that done by excel is

Eigen vectors are: A=0.149846, B=0.181210, C=0.024420, D=0.034484, E=0.059444, F=0.056325, G=0.299623, H=0.099635, I=0.066852, J=0.028487

Λmax=10.527

CI=0.0585

From corresponding values from large samples of matrices of purely random judgments' for n=10 is 1.49

Then CR=CI/1.49

CR=0.0393<0.1 safe or consistent

Criteria4 (weather condition) candidate locations pair wise comparison matrix

Table 4.8: Pair wise comparison matrix for selection criteria 4(Source: group of experts)

	A			B			C			D			E			F			G			H			I			J		
A	1	1	1	1	1	1	1	1	1	4	5	6	1	1	1	1	1	1	1/3	1/2	1/3	1	1	1	1	1	1	1	1	1
B	1	1	1	1	1	1	1	1	1	4	5	6	1	1	1	1	1	1	1/3	1/2	1/3	1	1	1	1	1	1	1	1	1
C	1	1	1	1	1	1	1	1	1	4	5	6	1	1	1	1	1	1	1/3	1/2	1/3	1	1	1	1	1	1	1	1	1
D	1/6	1/5	1/4	1/6	1/5	1/4	1/6	1/5	1/4	1	1	1	1/6	1/5	1/4	1/6	1/5	1/4	1/6	1/5	1/4	1/6	1/5	1/4	1/6	1/5	1/4	1/6	1/5	1/4
E	1	1	1	1	1	1	1	1	1	4	5	6	1	1	1	1	1	1	1/3	1/2	1/3	1	1	1	1	1	1	1	1	1
F	1	1	1	1	1	1	1	1	1	4	5	6	1	1	1	1	1	1	1/3	1/2	1/3	1	1	1	1	1	1	1	1	1
G	1	2	3	1	2	3	1	2	3	7	8	9	1	2	3	1	2	3	1	1	1	1	2	3	1	2	3	1	2	3
H	1	1	1	1	1	1	1	1	1	4	5	6	1	1	1	1	1	1	1/3	1/2	1/3	1	1	1	1	1	1	1	1	1
I	1	1	1	1	1	1	1	1	1	4	5	6	1	1	1	1	1	1	1/3	1/2	1/3	1	1	1	1	1	1	1	1	1
J	1	1	1	1	1	1	1	1	1	4	5	6	1	1	1	1	1	1	1/3	1/2	1/3	1	1	1	1	1	1	1	1	1

Result from the weight calculation that done by excel is

Eigen vectors are: A=0.09685, B=0.096857, C=0.096857, D=0.03821, E=0.096857, F=0.096857, G=0.1869227, H=0.096857, I=0.096857, J=0.096857

Λmax=10.3977, CI=0.0441

From corresponding values from large samples of matrices of purely random judgments’ for n=10 is 1.49

Then CR=CI/1.49

CR=0.0296<0.1 safe or consistent

Criteria 5 (cost, availability of skill and production of labor) candidate locations pair wise comparison matrix

Table 4.9: Pair wise comparison matrix for selection criteria 5(Source: group of experts)

	A			B			C			D			E			F			G			H			I			J		
A	1	1	1	1	2	3	1/3	1/2	1	1/3	1/2	1	1	1	1	1	2	3	4	5	6	4	5	6	1	1	1	1	1	1
B	1/3	1/2	1	1/3	1/2	1	1	1	1	1	1	1	1	1	1	1	1	1	4	5	6	4	5	6	1	1	1	1	1	1
C	1	2	3	1	2	3	1	1	1	1	1	1	1	1	1	1	1	1	4	5	6	4	5	6	1	1	1	1	1	1
D	1	2	3	1	2	3	1	1	1	1	1	1	1	1	1	1	1	1	4	5	6	4	5	6	1	1	1	1	1	1
E	1	2	3	1	2	3	1	1	1	1	1	1	1	1	1	1	1	1	4	5	6	4	5	6	1	1	1	1	1	1
F	1/3	1/2	1	1/3	1/2	1	1	1	1	1	1	1	1	1	1	1	1	1	4	5	6	4	5	6	1	1	1	1	1	1
G	1/3	1/2	1	1/6	1/5	1/4	1/6	1/5	1/4	1/6	1/5	1/4	1/6	1/5	1/4	1/6	1/5	1/4	1	1	1	1/3	1/2	1	1/6	1/5	1/4	1	1	1
H	1/3	1/2	1	1/6	1/5	1/4	1/6	1/5	1/4	1/6	1/5	1/4	1/6	1/5	1/4	1/6	1/5	1/4	1	2	3	1	2	3	1	1	1	1	1	1
I	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1/3	1/2	1	4	5	6	4	5	6	1	1	1	1	1	1
J	1	2	3	1	1	1	1	1	1	1	1	1	1	1	1	1	2	3	4	5	6	4	5	6	1	1	1	1	1	1

Result from the weight calculation that done by excel is

Eigen vectors are: A=0.093167, B=0.098468, C=0.138359, D=0.145017, E=0.136739, F=0.111066, G=0.023848, H=0.040990, I=0.094555, J=0.117790,Λmax=10.851, CI=0.0945

From corresponding values from large samples of matrices of purely random judgments' for n=10 is 1.49

Then CR=CI/1.49, CR=0.0634<0.1 safe or consistent

Criteria 6(construction cost and land price) candidate locations pair wise comparison matrix

Table 4.10: Pair wise comparison matrix for selection criteria 6(Source: group of experts)

	A			B			C			D			E			F			G			H			I			J		
A	1	1	1	1	1	1	1	2	3	1	2	3	1	1	1	1	2	3	1/6	1/5	1/4	1/3	1/2	1	1	1	1	1	2	3
B	1	1	1	1	1	1	1	2	3	4	5	6	1	2	3	1	2	3	1/6	1/5	1/4	1	2	3	1	1	1	1	2	3
C	1/3	1/2	1	1/3	1/2	1	1	1	1	1	2	3	1/3	1/2	1	1/3	1/2	1	1/9	1/9	1/9	1/9	1/8	1/7	1/3	1/2	1	1	1	1
D	1/3	1/2	1	1/6	1/5	1/4	1/3	1/2	1	1	1	1	1/3	1/2	1	1/3	1/2	1	1/9	1/9	1/9	1/6	1/5	1/4	1/6	1/5	1/4	1/6	1/5	1/4
E	1	1	1	1/3	1/2	1	1	2	3	1	2	3	1	1	1	1	2	3	1/6	1/5	1/4	1/3	1/2	1	1/3	1/2	1	1	2	3
F	1/3	1/2	1	1/3	1/2	1	1	2	3	1	2	3	1/3	1/2	1	1	1	1	1/6	1/5	1/4	1/3	1/2	1	1/3	1/2	1	1	1	1
G	4	5	6	4	5	6	9	9	9	9	9	9	4	5	6	4	5	6	1	1	1	4	5	6	1	2	3	4	5	6
H	1	2	3	1/3	1/2	1	7	8	9	4	5	6	1	2	3	1	2	3	1/6	1/5	1/4	1	1	1	1	1	1	1	2	3
I	1	1	1	1	1	1	1	2	3	4	5	6	1	2	3	1	2	3	1/3	1/2	1	1	1	1	1	1	1	1	1	1
J	1/3	1/2	1	1/3	1/2	1	1	1	1	1/3	1/2	1	1/3	1/2	1	1	1	1	1/6	1/5	1/4	1/3	1/2	1	1	1	1	1	1	1

Result from the weight calculation that done by excel is

Eigen vectors are: A=0.093358, B=0.098373, C=0.138225, D=0.144877, E=0.136607, F=0.110959, G=0.24078, H=0.041384, I=0.094464, J=0.117677, Λ max=10.87

CI=0.0968

From corresponding values from large samples of matrices of purely random judgments' for n=10 is 1.49

Then CR=CI/1.49, CR=0.065<0.1 safe or consistent

Final result or Value for money (VFM) calculation result and Option performance matrix table

Table 4.11: VFM table (Source: result from excel calculation by researcher)

	1	2	3	4	5	6	VFM	RANK
A	0.108	0.0184	0.0704	0.012	0.0033	0.048	**0.1197**	**3**
B	0.0132	0.0368	0.0836	0.012	0.003	0.0066	**0.1552**	**2**
C	0.006	0.0138	0.0132	0.0108	0.0039	0.0024	0.0501	8
D	0.006	0.0069	0.0176	0.0024	0.0039	0.0018	0.0386	10
E	0.006	0.0115	0.0264	0.012	0.0048	0.0048	0.0649	6
F	0.006	0.0155	0.022	0.012	0.0033	0.0036	0.0584	7
G	0.0336	0.0805	0.1232	0.0228	0.0009	0.0198	**0.2808**	**1**
H	0.0192	0.0253	0.0396	0.012	0.0012	0.0072	**0.1045**	**4**
I	0.0096	0.0138	0.0308	0.012	0.003	0.006	0.0752	5
J	0.0072	0.0092	0.0132	0.012	0.0033	0.003	0.0479	9

As we can see from the above option performance matrix(OPM) table, locations G,B,A,H ranks one up to four respectively base on the ,VFM(value for money), which will be the four site locations to construct the warehouses.

These are **G: Hawassa, B: Aleta Wondo, A: Bensa Daayye, and H: Yirgalem**

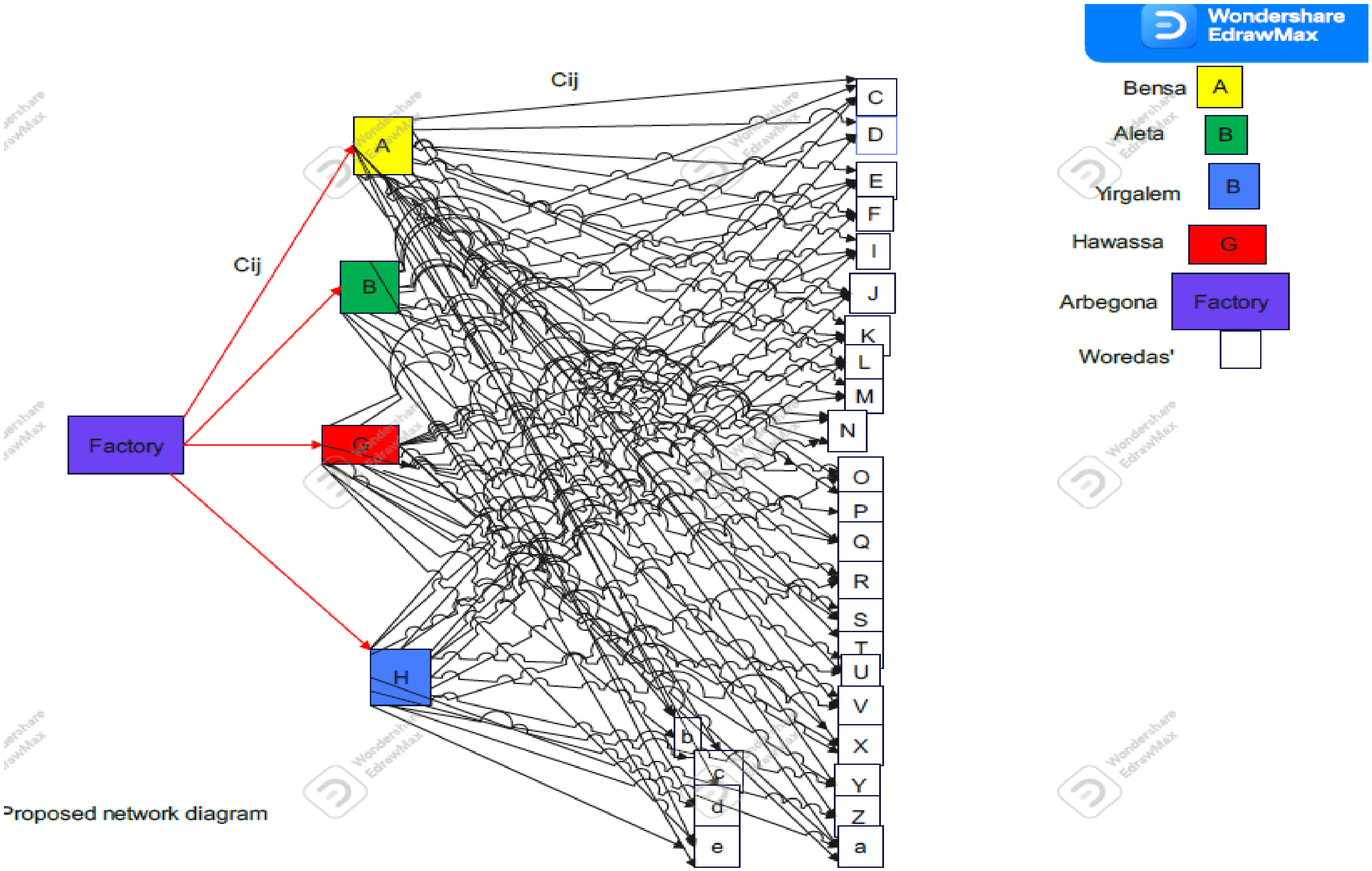


Figure 4: a proposed network diagram

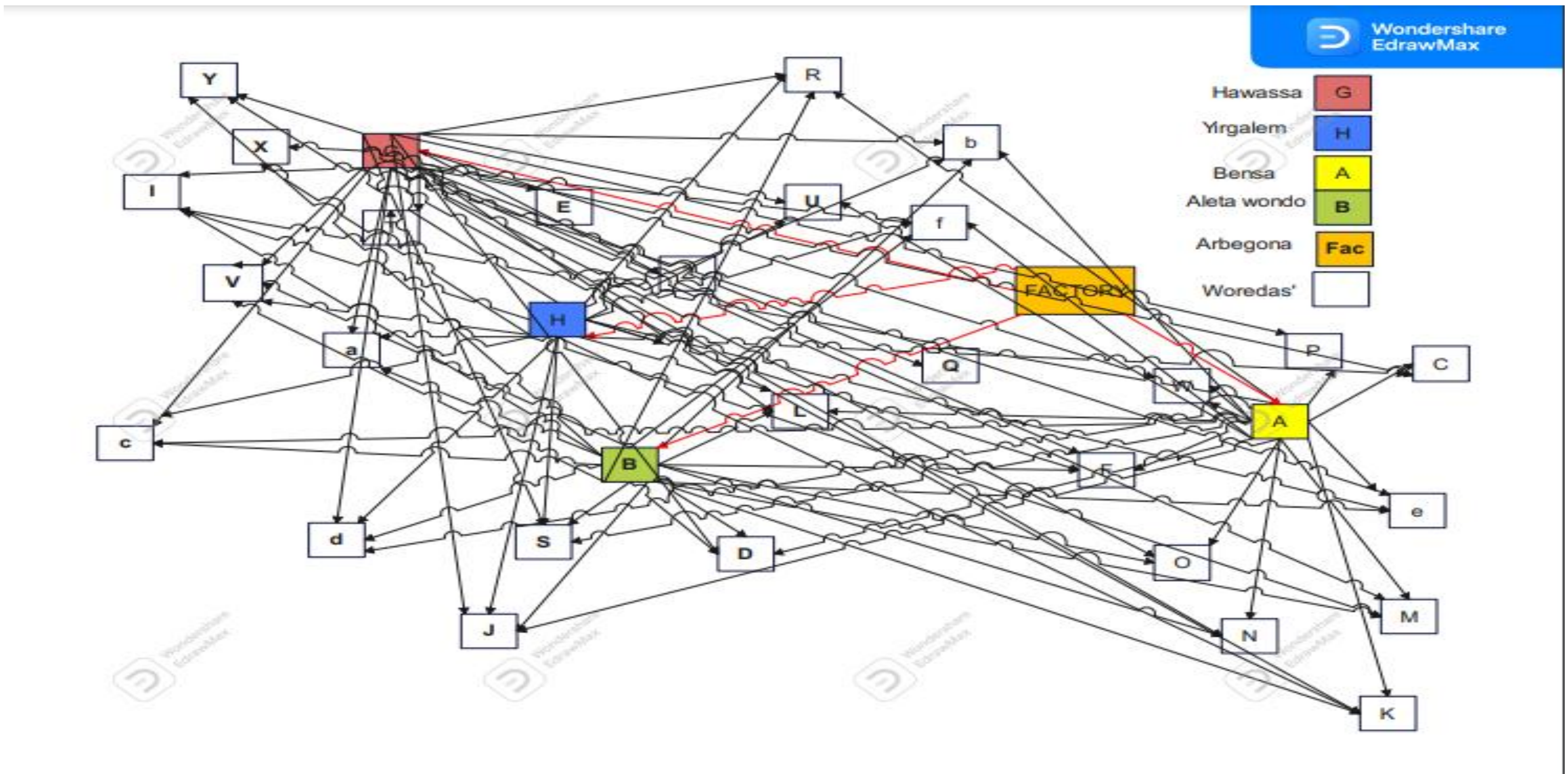


Figure 5: a proposed network with respect to its geographical locations

Assumptions of the above network:

As we can see in above figure four supply points or regional warehouses has to established based on demand information to satisfy the demands in a region.

4.4.4. Calculating optimal cost of distribution

Before we calculate any cost of distribution we should determine demand and supply location and their respective distances from each supply point to each demand points.

The following table illustrates distances in kilometers from each supply point or from each regional warehouse to each demand point or customer.

Table 4.12: Transshipment points and their distance from the factory (Source: SNRS road transport office)

From/To	Transshipment point and their distance from the factory In Km				
	A	B	G	H	Total supply
Factory	25	63	77	98	2,275,800 packs/week

Table4.13: demand locations and respective distances from the supply point (Source: SNRS road transport office)

From/ To	Demand locations and their distances from the Transshipment supply point																
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Total supply
1. A	0	68	68	75	111	21	132	93	117	95	44	65	42	44	24	42	
2. B	68	0	136	35	47	51	67	31	53	39	112	24	110	102	92	110	
3. G	132	67	200	98	24	111	0	43	29	84	176	84	169	166	156	174	
4. H	93	31	163	62	31	78	43	0	37	55	139	41	137	129	119	137	
Total Demand	**11000**	**16500**	**5100**	**5300**	**5500**	**5300**	**51000**	**16500**	**2400**	**5500**	**5300**	**1650**	**5500**	**1650**	**2400**	**1650**	
From/ To	Q	R	S	T	U	V	W	X	Y	Z	AA	BB	CC	DD	EE	FF	
1. A	36	134	77	115	144	134	31	156	167	106	130	130	110	73	63	150	
2. B	37	74	46	50	60	80	61	91	102	44	66	66	56	15	110	86	
3. G	97	20	106	12	45	37	121	24	38	56	56	24	57	60	166	44	
4. H	64	54	73	32	34	60	88	71	82	17	32	48	29	31	133	68	
Total Demand	**5300**	**5500**	**1650**	**2400**	**1650**	**2400**	**1650**	**2400**	**2400**	**2400**	**2400**	**5300**	**2400**	**5500**	**2400**	**1650**	

Table4.14: demand locations and their respective unit transportation cost

From/ To			Demand locations and their transportation cost from the supply point per pack per birr														
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Total supply
1. A	0	3.944	3.944	4.35	6.438	1.218	7.656	5.394	6.786	5.51	2.552	3.77	2.436	2.552	1.392	2.436	
2. B	3.944	0	7.888	2.03	2.726	2.958	3.886	1.798	3.074	2.262	6.496	1.392	6.38	5.916	5.336	6.38	
3. G	7.656	3.886	11.6	5.684	1.392	6.438	0	2.494	1.682	4.872	10.208	4.872	9.802	9.628	9.048	10.092	
4. H	5.394	1.798	9.454	3.596	1.798	4.524	2.726	0	2.146	3.19	8.062	2.378	7.946	7.482	6.902	7.946	
Total Demand	**11000**	**16500**	**5100**	**5300**	**5500**	**5300**	**51000**	**16500**	**2400**	**5500**	**5300**	**1650**	**5500**	**1650**	**2400**	**1650**	
From/ To	Q	R	S	T	U	V	W	X	Y	Z	a	b	c	d	e	f	
1. A	2.088	7.772	4.466	6.67	8.352	7.772	1.798	9.048	9.686	6.148	7.54	7.54	6.38	4.234	3.654	8.7	
2. B	2.146	4.292	2.668	2.9	3.48	4.64	3.538	5.278	5.916	2.552	3.828	3.828	3.248	0.87	6.38	4.988	
3. G	5.626	1.16	6.148	0.696	2.61	2.146	7.018	1.392	2.204	3.248	3.248	1.392	3.306	3.48	9.628	2.552	
4. H	3.712	3.132	4.234	1.856	1.972	3.48	5.104	4.118	4.756	0.986	1.856	2.784	1.682	1.798	7.714	3.944	
Total Demand	**5300**	**5500**	**1650**	**2400**	**1650**	**2400**	**1650**	**2400**	**2400**	**2400**	**2400**	**5300**	**2400**	**5500**	**2400**	**1650**	

And to calculate the optimal transportation cost and to allocate the regional warehouse for demand location the transshipment model is used.

After utilizing equation (2.1), (2.2), (2.3), and (2.4) the objective function becomes:

$Z_{min}=1.45X_{FA}+3.654X_{FB}+4.466X_{FG}++4.87X_{FH}+1.67X_{1A}+6.20+X_{1B}+6.07X_{1C}+6.07X_{1D}+9.07X_{1E}+$

$3.07X_{1F}+10.47X_{1G}+8.00X_{1H}+10.67X_{1I}+7.80X_{1J}+4.60X_{1K}+4.87X_{1L}+4.47X_{1M}+X_{1N}+3.26X_{1O}+4.20$

$X_{1P}+4.47X_{1Q}+4.07X_{1R}+6.80X_{1S}+10.61X_{1T}+9.34X_{1U}+7.01X_{1V}+10.61X_{1W}+3.74X_{1X}+12.07X_{1Y}+1$

$2.80X_{1Z}+8.60X_{1a}+10.94X_{1b}+10.34X_{1c}+9.01X_{1d}+6.74X_{1e}+6.14X_{1f}+9.0X_{2A}+4.14X_{2B}+13.54X_{2C}+6.$

$54X_{2D}+7.38X_{2E}+7.61X_{2F}+8.67X_{2G}+6.27X_{2H}+8.94X_{2I}+6.07X_{2J}+11.94X_{2K}+5.80X_{2L}+11.80X_{2M}+X$

${}_{2N}+10.60X_{2O}+11.54X_{2P}+11.81X_{2Q}+6.67X_{2R}+7.27X_{2S}+9.00X_{2T}+7.54X_{2U}+9.54X_{2V}+9.54_{2W}+7.47$

$X_{2X}+10.34X_{2Y}+11.14X_{2Z}+6.87X_{1a}+9.14X_{2b}+8.60X_{2c}+6.87X_{2d}+5.20X_{2e}+11.34X_{2f}+13.74X_{3A}+9.1$

$4X_{3B}+18.28X_{3C}+11.27X_{3D}+6.47X_{3E}+5.67X_{3F}+5.14X_{3G}+7.81X_{3H}+6.80X_{3I}+10.33X_{3J}+16.41X_{3K}+$

$10.54X_{3L}+15.94X_{3M}+X_{3N}+15.34X_{3O}+16.01X_{3P}+16.54X_{3Q}+11.34X_{3R}+12.01X_{3S}+6.27X_{3T}+5.74X_{3}$

${}_{U}+7.40X_{3V}+7.94X_{3W}+12.47X_{3X}+6.54X_{3Y}+7.27X_{3Z}+8.67X_{3a}+8.67X_{3b}+6.54X_{3c}+8.54X_{3d}+8.94X_{3e}$

$+7.34X_{3FF}+12.21X_{4A}+8.07X_{4B}+17.81X_{4C}+10.14X_{4D}+8.07X_{4E}+11.21X_{4F}+9.14X_{4G}+6.47X_{4H}+9.54$

$X_{4I}+9.67X_{4J}+15.61X_{4K}+9.40X_{4L}+15.41X_{4M}+X_{4N}+14.21X_{4O}+15.14X_{4P}+15.41X_{4Q}+10.27X_{4R}+10.$

$87X_{4S}+9.54X_{4T}+8.14X_{4U}+10.01X_{4V}+9.60X_{4W}+11.07X_{4X}+10.74X_{4Y}+11.42X_{4Z}+7.14X_{a}+8.14X_{4b}+$

$9.20X_{4c}+7.948.07X_{4d}+8.07X_{4e}+8.81X_{4f}$

Subjected to:

$X_{FA}+X_{FB}+X_{FG}+X_{FH}=2,275,800$ Supply constraint

$X_{1A}+X_{2A}+X_{3A}+X_{4A}=11000$

$X_{1B}+X_{2B}+X_{3B}+X_{4B}=16500$

$X_{1C}+X_{2C}+X_{3C}+X_{3D}=5100$

$X_{1D}+X_{2D}+X_{3D}+X_{4D}=5300$

$X_{1E}+X_{2E}+X_{3E}+X_{4E}=5500$

$X_{1F} + X_{2F} + X_{3F} + X_{4F} = 5300$

$X_{1G} + X_{2G} + X_{3G} + X_{4G} = 51000$

$X_{1H} + X_{2H} + X_{3H} + X_{4H} = 16500$

$X_{1I} + X_{2I} + X_{3I} + X_{4I} = 2400$

$X_{1J} + X_{2J} + X_{3J} + X_{4J} = 5500$

$X_{1K} + X_{2K} + X_{3K} + X_{4K} = 5300$

$X_{1L} + X_{2L} + X_{3L} + X_{3L} = 1650$

$X_{1M} + X_{2M} + X_{3M} + X_{4M} = 5500$

$X_{1N} + X_{2N} + X_{3N} + X_{4N} = 1650$

$X_{1O} + X_{2O} + X_{3O} + X_{4O} = 2400$

$X_{1P} + X_{2P} + X_{3P} + X_{4P} = 1650$

$X_{1Q} + X_{2Q} + X_{3Q} + X_{4Q} = 5300$

$X_{1R} + X_{2R} + X_{3R} + X_{4R} = 1650$

$X_{1S} + X_{2S} + X_{3S} + X_{4S} = 5500$

$X_{1U} + X_{2U} + X_{3U} + X_{4U} = 2400$

$X_{1V} + X_{2V} + X_{3V} + X_{3V} = 1650$

$X_{1W} + X_{2W} + X_{3W} + X_{4W} = 2400$

$X_{1X} + X_{2X} + X_{3X} + X_{4X} = 1650$

$X_{1Y} + X_{2Y} + X_{3Y} + X_{4Y} = 2400$

$X_{1Z} + X_{2Z} + X_{3Z} + X_{4Z} = 2400$

$X_{1a} + X_{2a} + X_{3a} + X_{4a} = 2400$

$X_{1b} + X_{2b} + X_{3b} + X_{4b} = 2400$

$X_{1c} + X_{2c} + X_{3c} + X_{4c} = 5300$

$X_{1d} + X_{2d} + X_{3d} + X_{4d} = 2400$

$X_{1e} + X_{2e} + X_{3e} + X_{3e} = 5500$

$X_{1f} + X_{2f} + X_{3f} + X_{4f} = 1650$demand constraint

$X_{F1}=1.67X_{1A}+6.20+X_{1B}+6.07X_{1C}+6.07X_{1D}+9.07X_{1E}+3.07X_{1F}+10.47X_{1G}+8.00X_{1H}+10.67X_{1I}+7.80X_{1J}+4.60X_{1K}+4.87X_{1L}+4.47X_{1M}+X_{1N}+3.26X_{1O}+4.20X_{1P}+4.47X_{1Q}+4.07X_{1R}+6.80X_{1S}+10.61X_{1T}+9.34X_{1U}+7.01X_{1V}+10.61X_{1W}+3.74X_{1X}+12.07X_{1Y}+12.80X_{1Z}+8.60X_{1a}+10.94X_{1b}+10.34X_{1c}+9.01X_{1d}+6.74X_{1e}+6.14X_{1f}$

$X_{F2}=9.0X_{2A}+4.14X_{2B}+13.54X_{2C}+6.54X_{2D}+7.38X_{2E}+7.61X_{2F}+8.67X_{2G}+6.27X_{2H}+8.94X_{2I}+6.07X_{2J}+11.94X_{2K}+5.80X_{2L}+11.80X_{2M}+X_{2N}+10.60X_{2O}+11.54X_{2P}+11.81X_{2Q}+6.67X_{2R}+7.27X_{2S}+9.00X_{2T}+7.54X_{2U}+9.54X_{2V}+9.54_{2W}+7.47X_{2X}+10.34X_{2Y}+11.14X_{2Z}+6.87X_{1a}+9.14X_{2b}+8.60X_{2c}+6.87X_{2d}+5.20X_{2e}+11.34X_{2f}$

$X_{F3}=13.74X_{3A}+9.14X_{3B}+18.28X_{3C}+11.27X_{3D}+6.47X_{3E}+5.67X_{3F}+5.14X_{3G}+7.81X_{3H}+6.80X_{3I}+10.33X_{3J}+16.41X_{3K}+10.54X_{3L}+15.94X_{3M}+X_{3N}+15.34X_{3O}+16.01X_{3P}+16.54X_{3Q}+11.34X_{3R}+12.01X_{3S}+6.27X_{3T}+5.74X_{3U}+7.40X_{3V}+7.94X_{3W}+12.47X_{3X}+6.54X_{3Y}+7.27X_{3Z}+8.67X_{3a}+8.67X_{3b}+6.54X_{3c}+8.54X_{3d}+8.94X_{3e}+7.34X_{3f}$

$X_{F4}=12.21X_{4A}+8.07X_{4B}+17.81X_{4C}+10.14X_{4D}+8.07X_{4E}+11.21X_{4F}+9.14X_{4G}+6.47X_{4H}+9.54X_{4I}+9.67X_{4J}+15.61X_{4K}+9.40X_{4L}+15.41X_{4M}+X_{4N}+14.21X_{4O}+15.14X_{4P}+15.41X_{4Q}+10.27X_{4R}+10.87X_{4S}+9.54X_{4T}+8.14X_{4U}+10.01X_{4V}+9.60X_{4W}+11.07X_{4X}+10.74X_{4Y}+11.42X_{4Z}+7.14X_{a}+8.14X_{4b}+9.20X_{4c}+7.948.07X_{4d}+8.07X_{4e}+8.81X_{4f}$Transshipment point constraint

$X_{ij} \geq 0$ non zero condition

4.5 Result Presentation

After solving the above LP model by using QM for Windows version 5.3 the following results found and attached under appendix III

The result from QM output shows that the total minimized optimal transportation cost of distribution is **=869,913birr/ week**

It can be seen from the result origin A (Bensa) should supply:

- Bensa
- Xexicha
- Bursa
- Cirre
- Girja
- Shafaamo
- Boona
- Ganbelto
- Daeela
- Arooreessa
- Cabbe

Origin B (Aleta) should supply:

- Aleta
- Bursa
- Daarra
- Cuukko
- Hagereselam
- Cirone
- Xexicha

Origin G (Hawassa) should supply:

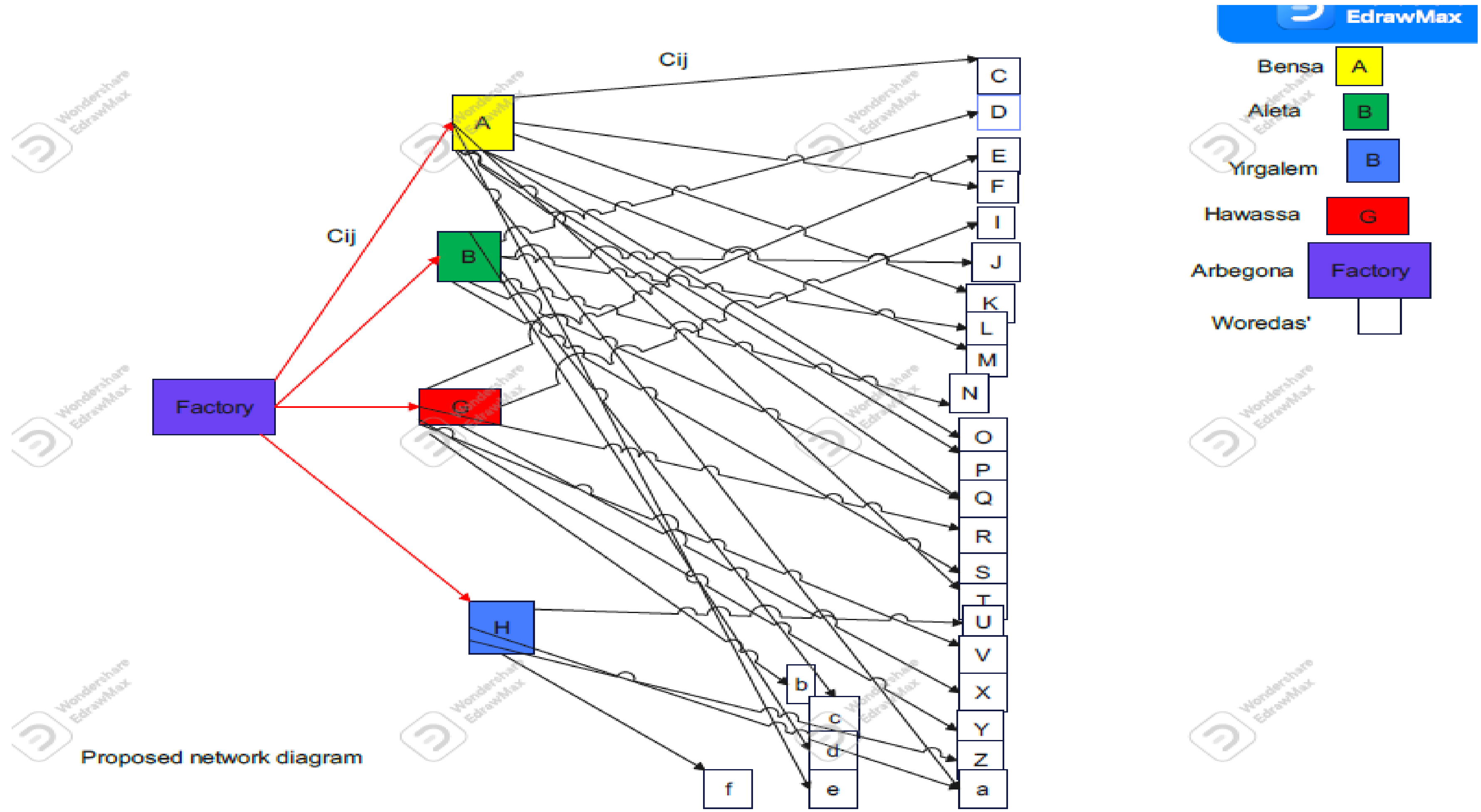
- Lekku
- Wondogenet
- Doore
- Guguma
- Hawassa
- Haweela
- Malga
- Boricha
- Shaamanna
- Gorche

And origin H (Yirgalem) should supply:

- Yirgalem
- Lokka Abaya
- Daraara
- Baleela
- Wonsho

4.4.3. A new Designed distribution network

The final cost effective distribution network becomes



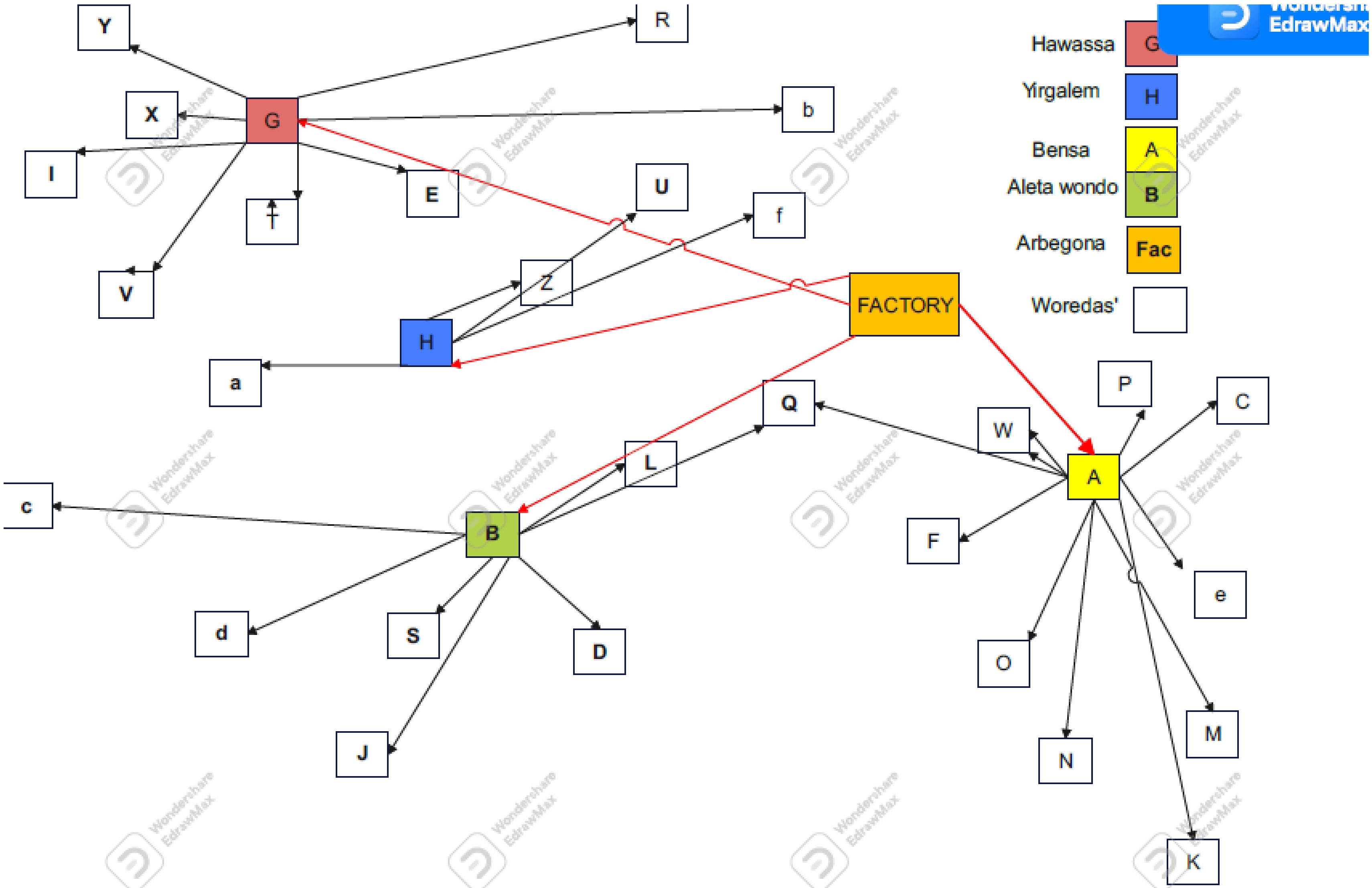


Figure 7: The final newly designed cost effective distribution network with respect to its geographical location

4.6. Compare and contrast the distribution networks

Here the existing cost of distribution and the optimal cost of distribution for newly designed network are compared:

To compare cost of distribution of the newly designed network to existing distribution cost;

Cost of distribution of existing network is=**1,252,039.90birr/week**

Cost of distribution of newly designed network is=**869,913birr/ week**

Cost difference **1,252,039.90birr/week-869,913birr/ week=382,126.90birr/week**

Total weekly demand=**189,650packs=2,275,800 bottle of 1.2l size**

To check how much cost is saved per bottle it can be found by: cost difference/total demand

=**950,275.90birr/week/2,275,800 bottle of 1.2l size=0.168cents/bottle**

The amount of money saved by implementing the newly designed network will be:

=**950275.90*4=3,801,103.60birr/month**

=3801103.60*12=13,756,568.40birr/year

This shows that the newly designed distribution network can and will save a company more than**13.7million birr annually** and this will have a huge impact on the profitability of the company.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Distribution is one of a key activity that determines the success and failure of a given supply chain. Nevertheless many manufacturing firms in our country do not care for their distribution practices. As this study showed majority of the manufacturing companies in Ethiopia do not have well designed distribution network for distributing their product and this is costing them their customers and directly affecting their profitability.

As this study shows the design of a distribution network maximizes the total profitability of a given company through minimizing its distribution cost and also it increases the customer satisfaction by responding to the customers at different area.

In addition to this a company with well designed distribution network can reach its customer regardless of their distance from the origin or the factory. This allows the companies to cover market ground as much as possible because the design considers the market areas without any bias that can be made if the product is distributed traditionally.

From the study it can be seen that poor customer satisfaction and not meeting the demand of the customers is due to poorly designed distribution network of the manufacturing companies.

To conclude, the manufacturing companies in Ethiopia should wake up and give an attention to their distribution culture because as this study showed a lot of money, energy and time can be saved by designing the distribution network right. The result of distribution network showed that the company, Garamba Bottling, can save a lot of money if it implements the distribution strategy designed by the researcher.

5.2. Recommendation

The researcher like to recommend Ethiopian manufacturing companies to start designing their distribution network and implementing them if they like to succeed in their business and to meet the demand of the consumers of the product.

The recommendation from this study to water bottling companies in the country is that they should revise their distribution strategies by focusing on each bottle manufactured because small cents that incurred per bottle could be millions of birr as it can be seen in the study and this shows the profitability of bottling companies can be affected by each bottle produced.

In addition the company under study, Garamba Bottling,

- Highly recommended to implement the distribution network designed in this study to improve its supply chain.
- Also the company should maximize its production by increasing the number of production lines to be competitive country nationwide and to satisfy the growing demand.

5.3 Future research direction

In conducting the literature review, some gaps in the area of a distribution network design were identified. Therefore, in line with the summarized gaps the following future direction can be given to extend the work of this study.

- This research was limited to Sidama National regional State and further research can be done for a distribution network design for the whole country.
- This research only considered the cost of distribution for designing a network and a future researcher can design a network by including related costs like cost of warehouse establishment, inventory holding cost, operating costs, insurance and taxes….

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Appendix I

Interview questions

Interview Guideline

- The researcher (interviewer) introduces himself/herself for the interviewee and asks for voluntariness to respond for the interview.

- The interviewee introduces himself for the researcher including his/her position in company, and responsibilities.

1. How is the company currently distributing its product i.e. on house or through an agent?
2. How much is the current cost of transportation to distribute the product?
3. What are the current destinations of the company product within the country and within SNRS and how is the order being placed by retailers or the customers?
4. How much is the production capacity of the production lines during its full potential and how many numbers of shifts is there?
5. What are the production and distribution challenges that are being faced by the company and how these barriers are affecting the customer satisfaction?
6. How many distribution centers and warehouses does the company currently have, how much is the capacity of those warehouses and does the company have any plan to establish additional distribution centers and warehouses?
7. How many retailers and distributors of SPW are there in each Demand points of SNRS and how much is the demand daily of each retail shop?
8. Who is supplying the retailers in each Demand points of SNRS or how do the retailers of the bottled water getting the product, SPW, and how much is the lead time?
9. How much is the availability of SPW in study area and how is SPW being liked by its consumers compared to similar products available in the area?

Appendix II

Values that is applicable for calculating the consistency ratio CR by using CI for the random judgments of the values from the Saaty Book.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Appendix III

Decision matrix filled by experts

Dear Sir/Madam

I am undertaking a research study entitled "a distribution network design for highly demanded commodity: case of south spring water" for the partial fulfillment of degree of masters in industrial engineering and logistics management

This questionnaire survey is used as input to my academic research that aims to design a distribution network for highly demanded commodity and its objective is to fill the pair wise comparison matrix filled by experts' judgment for the selection of the candidate locations to construct warehouses by using AHP technique.

Since you are expert in issues related to AHP and familiar with the study are, you are chosen to fill the questionnaire of pair wise comparison decision matrix prepared. I appreciate your valuable contribution to field of industrial engineering and to my study by completing all questions by taking you precious time. And all information given will be strictly used for academic purposes.

With best Regards!!

TsegaabTesema

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Pair wise comparison matrix filled by Expert

Location selecting criteria and their representation

Selecting criteria	Its representation
Cost and availability of energy/ utilities	1
Business climate	2
Proximity to customer	3
Weather	4
Cost availability, skill and productivity of labor	5
Construction costs and land price	6

Here are list of candidate Demand points and city administrations for establishing potential regional warehouse with respect to their representation

- ✓ BensaDaayye=A
- ✓ Aletawondo=B
- ✓ Cirre=C
- ✓ Hagere selam=D
- ✓ Lekku=E
- ✓ Boona=F
- ✓ Hawassa=G
- ✓ Yirgalem=H
- ✓ Cuukko=I
- ✓ Daarra=J

The matrix table for decision criteria is

Decision criteria's	1	2	3	4	5	6
1	1	1/2	1/5	1	4	3
2	2	1	1/3	2	6	4
3	5	3	1	5	9	7
4	1	1/2	1/5	1	4	3
5	1/4	1/6	1/9	1/4	1	1/3
6	1/3	1/4	1/7	1/3	3	1

Criteria 1 (cost, availability of energy and utilities) candidate locations pair wise comparison matrix

Candidate locations	A	B	C	D	E	F	G	H	I	J
A	1	1/2	2	2	2	2	1/4	1/2	1	2
B	2	1	3	3	3	3	1/3	1	2	3
C	1/2	1/3	1	1	1/2	1	1/6	1/5	1/2	1
D	1/2	1/3	1	1	1	1	1/5	1/4	1/2	1

E	1/2	1/3	2	1	1	1/2	1/5	1/3	1	1/2
F	1/2	1/3	1	1	2	1	1/5	1/4	1/3	1
G	4	3	6	5	5	5	1	3	4	6
H	2	1	5	4	3	4	1/3	1	2	3
I	1	1/2	2	2	1	3	1/4	1/2	1	2
J	1/2	1/3	1	1	2	1	1/3	1/3	1/2	1

Criteria2(Business climate) candidate locations pair wise comparison matrix

Candidate locations	A	B	C	D	E	F	G	H	I	J
A	1	1/2	2	3	2	3	1/5	1/2	2	3
B	2	1	2	4	3	4	1/3	2	2	3
C	1/2	1/2	1	3	1	1	1/7	1/3	1	2
D	1/3	1/4	1/3	1	1/2	1/2	1/9	1/5	1/4	1
E	1/2	1/3	1	2	1	1/2	1/7	1/3	1	1/3
F	1/3	1/4	1	2	2	1	1/7	1/3	1	2
G	5	3	7	9	7	7	1	5	6	9
H	2	1/2	3	5	3	3	1/5	1	2	4
I	1/2	1/2	1	4	1	1	1/6	1/2	1	2
J	1/3	1/3	1/2	1	3	1/2	1/9	1/4	1/2	1

Criteria 3(proximity to market) candidate locations pair wise comparison matrix

Candidate locations	A	B	C	D	E	F	G	H	I	J
A	1	1	5	5	4	4	1/3	1	2	5
B	1	1	6	6	5	5	1/3	2	3	5
C	1/5	1/6	1	1	1/2	1	1/6	1/5	1/2	1
D	1/5	1/6	1	1	1/2	1/2	1/5	1/3	1/2	1
E	1/4	1/5	3	2	1	1	1/7	1/2	2	3
F	1/4	1/5	3	2	1	1	1/6	1/2	1	3
G	3	3	7	5	4	6	1	4	5	9
H	1	1/2	5	3	2	2	1/4	1	1	3
I	1/2	1/3	6	2	1/2	1	1/5	1	1	2
J	1/5	1/5	1	1	1/3	1/3	1/9	1/3	1/2	1

Criteria4(weather condition) candidate locations pair wise comparison matrix

Candidate locations	A	B	C	D	E	F	G	H	I	J
A	1	1	1	5	1	1	1/2	1	1	1
B	1	1	1	5	1	1	1/2	1	1	1
C	1	1	1	5	1	1	1/2	1	1	1
D	1/5	1/5	1/5	1	1/5	1/5	1/7	1/5	1/5	1/5
E	1	1	1	5	1	1	1/2	1	1	1
F	1	1	1	5	1	1	1/2	1	1	1
G	2	2	2	7	2	2	1	2	2	2
H	1	1	1	5	1	1	1/2	1	1	1
I	1	1	1	5	1	1	1/2	1	1	1
J	1	1	1	5	1	1	1/2	1	1	1

Criteria 5 (cost, availability of skill and production of labor) candidate locations pair wise comparison matrix

Candidate locations	A	B	C	D	E	F	G	H	I	J
A	1	2	1/3	1/3	1	2	4	3	1	1/3
B	1/2	1/2	1	1	1	1	4	3	1	1
C	3	2	1	1	1	1	5	3	1	1
D	3	2	1	1	1	1	6	4	1	1
E	2	2	1	1	1	1	5	4	1	1
F	1/2	1/2	1	1	1	1	5	4	2	1
G	1/3	1/4	1/5	1/6	1/5	1/5	1	1/2	1/4	1/6
H	1/3	1/4	1/5	1/4	1/4	1/4	2	1	1	1
I	1	1	1	1	1	1/2	4	1	1	1
J	3	1	1	1	1	1	6	1	1	1

Criteria6(construction cost and land price) candidate locations pair wise comparison matrix

Candidate locations	A	B	C	D	E	F	G	H	I	J
A	1	1	3	3	1	2	1/3	1/2	1	3
B	1	1	3	4	3	2	1/5	2	1	3

C	1/3	1/3	1	1	1/2	1/2	1/9	1/7	1/3	1
D	1/3	1/4	1/3	1	1/2	1/2	1/9	1/4	1/4	1/4
E	1	1/3	2	2	1	2	1/5	1/2	1/2	2
F	1/2	1/2	2	2	1/2	1	1/6	1/2	1/2	1
G	5	5	9	9	5	6	1	4	3	5
H	2	1/2	7	4	2	2	1/4	1	1	3
I	1	1	3	4	2	2	1/3	1	1	2
J	1/3	1/3	1	2	1/2	1	1/5	1/3	1/2	1

Appendix IV

Result tables of transshipment problem analysis by using QM for windows version 5.3

Objective: ○ Maximize ◉ Minimize

Starting method: Any starting method

untitled) Solution

solution value = $869913	A	B	C	D	E	F	G
1	11000		5100			5300	
2		16500		5300			
3					5500		510(
4							

Objective: ○ Maximize ◉ Minimize

Starting method: Any starting method

(untitled) Solution

H	I	J	K	L	M	N	O
			5300		5500	1650	2400
		5500		1650			
	2400						
16500							

Objective

- Maximize
- (•) Minimize

Starting method

Any starting method

(untitled) Solution

	P	Q	R	S	T	U	V	W
400	1650	5300		1650				1650
			5500		2400		2400	
						1650		

Objective

- Maximize
- (•) Minimize

Starting method

Any starting method

(untitled) Solution

X	Y	Z	AA	AB	AC	AD	AE	AF
							2400	
						5500		
	2400			5300				1650
2400		2400	2400		2400			