SUPPLY CHAIN NETWORK DESIGN AND ANALYSIS USING SIMULATION TECHNIQUE: CASE OF KOJJ FOOD COMPLEX

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This is to certify that the thesis prepared by Tewodros Tolosa, entitled: "supply chain network design and analysis using simulation technique: case of kojj food complex "and submitted in partial fulfillments of the requirements for the degree of Master of Science (Mechanical and Industrial Engineering) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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DECLARATION

I hereby declare that the work which is being presented in this thesis entitle “supply chain network development using simulation analysis in case of KOJJ food complex” is original work of my own, has not been presented for a degree of any other university and all the resources of materials used for the thesis have been properly acknowledged.

____________________ ________________

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

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Dr. Yitagesu Yilma Date

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ABBREVIATION'S

- SCM: - supply chain management
- ICT: - information and communication technology
- FCTP: - The fixed-charge transportation problem
- MST: - minimum spanning tree
- JIT: -Just-In-Time
- SRM: -supplier relationship management
- SNM: - supplier network management
- CRM: - customer relationship management
- VECM: - vector error correction model
- SCOR: - Supply Chain Operations Reference
- WVC: -Wheat Value Chain
- WIP: - Work in progress
- SNNPR: - Southern Nations, Nationalities, and Peoples Region
- EMA: - Ethiopian mill association
- NGO: - Non-governmental organization
- WPI: - Wheat processing industries
- PDCA: - plan-do-check-act
- VAM: - Vogel's approximation model
- MM: - Mathematical Model

ANNEX

ABSTRACT

Now a day's world market, managing the whole supply chain system becomes a critical factor for the successful business. This thesis paper tries to identify the existing problems of the case company through scientific problem identification method and collect data to analyze the critical causes of the identified supply chain problems. it uses arena simulation software for modeling and analyzing the supply chain system for 1000hrs replication length. then, the paper obtained the following results: the company needs to work on raw material supply part by using transportation cost optimization method, the utilization of resources (trucks and labors) shows the rate at which the resources be busy during the simulation time. trucks utilization is about 53.8 and the utilization of labors is about 58.4 busy in the stated simulation run length. And finally, inventory management system point milling machine utilization is about 51 % busy in the afore mentioned simulation run length. The operators in packaging process operate with 59 %. finally, the paper concluded by developing the optimized and logical supply chain network system for the case company.

Key word: simulation, supply chain

CAPTER ONE: BACKGROUND AND JUSTIFICATUION OF THE STUDY

1. INTRODUCTION

For a long period of time, there has been an increasing interest in the use of supply chain methods to improve performance across the entire business enterprise. Supply chain management has become a standard part of business, and many companies now have a functional supply chain group. In addition to individual companies, many industries have recognized the importance of supply chain integration. Initiatives that aim at getting multiple companies to work together toward a more easy and efficient supply chain developed. The most well-known of such industry wide initiatives include the Quick Response of the clothing industry, the Efficient Consumer Response of the food industry, the Efficient Foodservice Response of the foodservice industry, as well as other initiatives in the pharmaceutical, automobile, aerospace, personal computer, and semiconductor industries. The affect the interest in supply chain management has led to innovative ways to re-engineer the supply chain, new software solutions to help companies plan and operate their supply chain, and new business models for existing and new players in the supply chain. The advances of the Internet have helped fuel the development of these innovations and new operating models. New ways to communicate, connect and collaborate among supply chain partners have comes forth. New connections of distribution as well as creative products and services have also come to the marketplace.(Terry P. Harrison, 2005)

In today's business environment, no enterprise can expect to build competitive advantage without integrating their strategies with those of supply chain systems in which they are entwined. In the past, what happened outside the four walls of the business was of secondary importance in comparison to the effective management of internal engineering, marketing, sales, manufacturing, distribution, and finance activities. The supply chain focus of today's enterprise has emerged in response to several critical business requirements that have arisen over the past two decades. To begin with, companies have begun to look to their supplier and customer channels as sources of cost reduction and process improvement. The goal is to relentlessly spread out all forms of waste where supply chain entities touch while enabling the creation of a linked, customer-centric, "virtual" supply channel capable of superlative quality and service.(Ross, 2011)

A supply chain consists of all group involved, directly or indirectly, in fulfilling a customer request. The supply chain includes not only manufacturer and suppliers, but also transporters, warehouses, retailers, and even customers themselves. Within each organization, such as a manufacturer, the supply chain includes all functional nodes involved in receiving and filling a customer request. These functions include, but are not limited to, marketing, operations, distribution, finance, and customer service.(Sunil Chopra, 2007)

To improve their activities, to gain competitive advantage companies are interested in effective and efficient supply chain operations that meet customer need. Therefore, the supply chain management SCM tasks to produce and distribute products in the right quantities to the right locations at the right time, while keeping costs down and customer service levels up. In essence, SCM aims to solve these tasks by searching for good advantages between system costs and customer satisfaction. Thus, SCM is interested in the efficient and cost-effective integration and coordination of suppliers, factories, warehouses and stores that establish the nodes of a supply chain.(Benkő, 2010)

Variation in wheat-marketed excess among wheat producers was another great challenge (Berhanu and Hoekstra, 2007). Thus, Ethiopian government has generically given a great room for industry chains to coordinate supply and demand issues at different functional nodes of value chain to guarantee continuous economic growth. Commonly, industry chains are streamlined as either supply or value chains is judged to mean the physical flow of commodities, which include input suppliers, service providers, producers, processors and traders. The wheat industry has many sectors, which are strongly interlinked to each other, that means the failure of one sector leads to a failure in another. For instance, if upstream actors fail to deliver the right quality and quantity of inputs at a right time to wheat producers, they cannot deliver the right quality and quantity of wheat demanded in downstream sector. (Bryce son and Kandampully 2004).

2. PROBLEM STATEMENT

Wheat is an important food crop in Ethiopia. According to the researchers (Woldehanna et al., 2010) and (Samuel g/selassie et al., 2017) the wheat sector faces different problems that include poor product quality, lack of market information and price instability are reported as major problems. And many of other operational constraints related to storage affects wheat trade. Wheat flour millers and bakeries indicate shortage of wheat as their primary problem. Poor quality of local wheat and lack of grade and standardization of traded wheat are other frequently reported problems.

According to annual report of the company (2015, 2016/2017ec) the case company faces different kinds of problems especially problems related to high transportation cost of distribution, the company spent much money to distribute its products because of complicated and unstudied vehicle routine ,inventory management system problem is the other critical problem of the company companies consecutive production results shows that the annual production of the company is decreased from the previous one. (2015 by 5% and 2016/2017 by 7%) the other operational problem of the company is raw material supply point the company has no relationship with the wheat producer/farmers even the farmers unions this gap opens to illegal Brokers' in increasing the raw material costs and highly distort information. Poor and unreliable grading and standard system creates for excessive intervention and according to the researcher survey the cost variation between brokers and wheat supply unions in the year of 2018 is about 25% per quintal in addition low wheat quality is recorded in order to increase the weight of the package 2-3% impurities per quintal, is purposely mixed. Therefore, this study tries to address these problems of the company.

3. RESEARCH QUESTION

1. What are the existing challenges on supply chain system of KOJJ food complex?
2. how to analyze the existing Supply chain system using simulation techniques of KOJJ food complex?

4. OBJECTIVES

4.1 General objectives

- Develop supply chain network design by investigating existing supply chain system for KOJJ food processing company.

4.2 Specific objectives

- Identify the existing supply chain system challenges of the company
- Evaluate the existing supply chain system of the company
- Propose supply chain network design by using simulation analysis technique.

5. SCOPE OF THE RESEARCH

The research entails an extensive literature study and focuses on how supply chain system performance can be improved by using simulation analysis techniques in KOJJ food complex company. The aim of the research mostly focuses on identifying the existing supply chain system problems and tries to analyze the performance by using arena simulation software. The research does not model every detail of the supply chain. Bu rather focuses on the problem areas.

6. SIGNIFICANCE

From this study there are several benefits and beneficiaries some of the important areas, like add knowledge in the area of supply chain optimization by using simulation techniques. For the sector, it points out the things that makes Ethiopian wheat supply chain difficult to full fill the intended quality and quantity. The other beneficiary is the case company, enable the host company more profitable and overcome challenges related to supply chain system. finally, the researchers who needs to study further being as a starting point.

7. RESEARCH ORGANIZATION

The research organized in six chapters. Chapter 1 begins with back ground and justification of the research. Chapter 2 is a literature review that discusses the fundamental concepts of supply chain network, application of computerized simulation analysis. Detail research methodology is state in chapter 3. Sector overview and introduce the case company covers the history, vision and mission of KOJJ food complex, in chapter 4. Chapter 5 is data collection and analysis. Network development and conclusion, recommendation and future work direction are presented in chapter six.

CHAPTER TWO: LITRATURE REVIEW

2.1 concept of supply chain

Supply chain is strategic channel management philosophy composed of the continuous rebuilding of networks of businesses integrated together through information technologies and choice to execute superlative, customer- winning value at the lowest cost through the digital, real-time arrangements of products and services, vital marketplace information, and logistics delivery capabilities with demand priorities. (Ross, 2011)

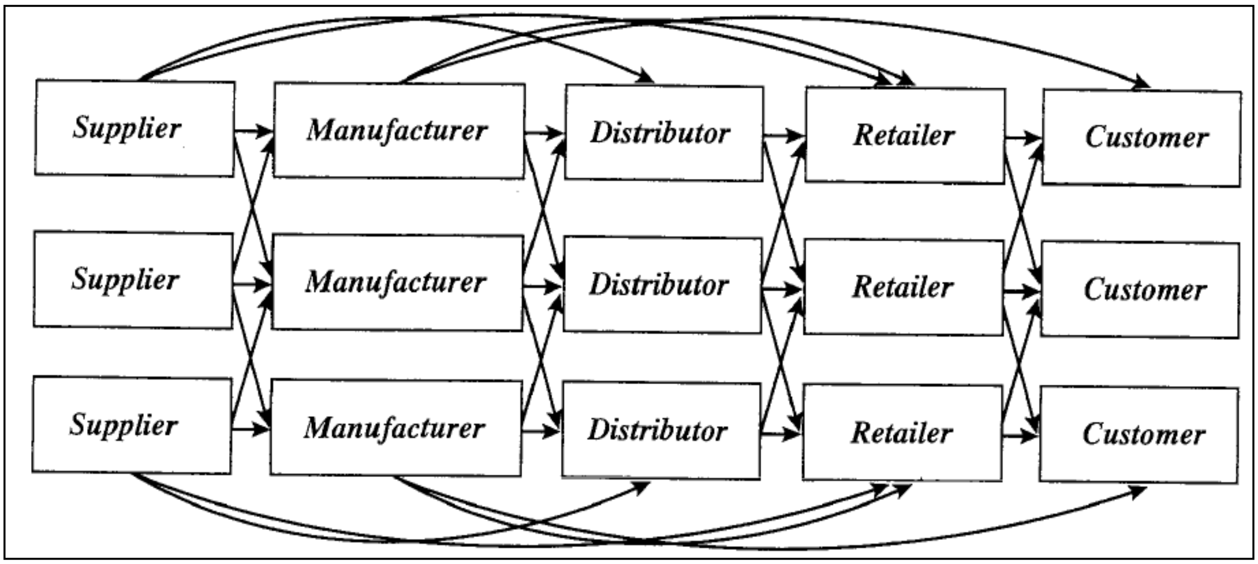


Fig 2.1: supply chain channels

Supply chain network design is the process of establishing network nodes and flow-paths in a supply chain. These nodes can represent either of manufacturing, storing, or distribution locations. This process helps plan the most suitable physical locations and their types that will constitute the supply chain for most efficient flow of materials and merchandise. Supply chain network design is a critical process for distribution demanding industries such as retail. In such industries, the cost of distribution of merchandise is a substantial part of their total operational costs. Large retailers typically have thousands of stores and may have hundreds of warehouses. An optimally designed network can actually reduce the costs and lead-time for distribution. This is also true for large manufacturers that have sellers, factories, and warehouses distributed across geographies and can benefit from optimizing their net workflow.(SEHGAL, 2009)

Some researchers (Christopher, 2005; Morgan, 2007) argued that the phrase „supply chain management‟ should be termed „demand chain management‟ and the word „network‟ should replace „chain‟. The supply network is a relatively recent area of serious research and the term „network‟ is preferred since the system includes multiple suppliers, suppliers to suppliers as well as multiple customers and customers‟ customers. Christopher (2005) defined supply network as "a network of connected and interdependent organizations mutually and co-operatively working together to control, manage and improve the flow of materials and information from suppliers to end users".

In the network approach, inter-organizational relationship is important for exchanging resources. Forms of collaboration are based on economic motivations, power, trust, and information sharing (Trienekens, 2003; Gimenez, 2006). The network design problem (for example, more than one hub integrated), in its general form, involves finding the optimum locations for the hub facilities, assigning non-hub origins and destinations to the centers, determining linkages between the hubs, and routing flows through the network (Groothedde et al, 2005). The bullwhip effect describes the phenomena of the adding of demand order variability's as they as they moved up the supply chain. The distortion of information throughout a supply chain can lead to large inefficiencies.

2.2 decision phases in supply chain

According to (chopra, Sunil 2007) the objective of every supply chain should be to maximize the overall value generated. The value a supply chain generates is the difference between what the final product is worth to the customer and the costs the supply chain incurs in filling the customer's request. For most commercial supply chains, value will be strongly correlated with supply chain profitability. The objective of every supply chain should be to maximize the overall value generated. The value a supply chain generates is the difference between what the final product is value to the customer and the costs the supply chain expose in filling the customer's request. For most commercial supply chains, value will be strongly correlated with supply chain profitability (also known as supply chain surplus), the difference between the revenue generated from the customer and the overall cost across the supply chain.

Supply Chain Design Strategy:

The marketing and pricing Plans for a product, a company decides how to structure the supply chain over the Next several years. It decides what the chain's form will be, how resources will allocate, and what processes each stage will perform.

Supply Chain Planning:

The goal of planning is to maximize the supply chain sexcess that can generate over the planning horizon given the constraints established during the strategic or design phase. Companies start the planning phase with a forecast for the coming year of demand in different markets.

Supply Chain Operation:

The goal of supply chain operations is to handle incoming customer orders in the best possible way. firms allocate inventory or production to individual orders, set a date that an order is to be filled, generate pick lists at a warehouse, and allocate an order to a particular shipping mode and shipment, set delivery schedules of trucks, and place replenishment orders.

2.3 supplier relationship management (SRM) concept

Herrmann and Hodgson (2001) defined SRM as a process involved in managing preferred suppliers and finding new ones whilst reducing costs, making purchasing predictable and repeatable, pooling buyer experience and extracting the benefits of supplier partnerships. It is focused on increasing the value of a manufacturer’s supply base by providing an integrated and holistic set of management tools focused on the interaction of the manufacturer with its suppliers. because doing business with correct suppliers is beneficial for the organization to provide enough production volume with good quality. Very few manufactures now own all the activities along the chain but integrate the supply network from various supplier networks and the ability to make fast and accurate decision often constitute a competitive advantage compared with the competitors or other networks. The rapid advance in information technology is now arrange not only to improve existing operational effectiveness of a business, but also to build the new capability to meet today’s business environment and complexity. Consequently, top management may feel hard to select the most appropriate supplier. SRM, a new category of supply chain applications, constitute to the supplier selection and thus increases the competitive advantage of the manufacturer through three primary mechanisms. (Aamodt, 1994).

SRM integrative framework

Framework is developed by (Park, 3 December 2009) for intertwined each function. When the functions are integrated, we should select suppliers who are suitable for the company's purchasing strategy. The selected suppliers' contribution to the company's performance will be evaluated through the collaboration, and, as a result of the evaluation, the supply quantity will be arranged and the support and development for the suppliers can be changed.

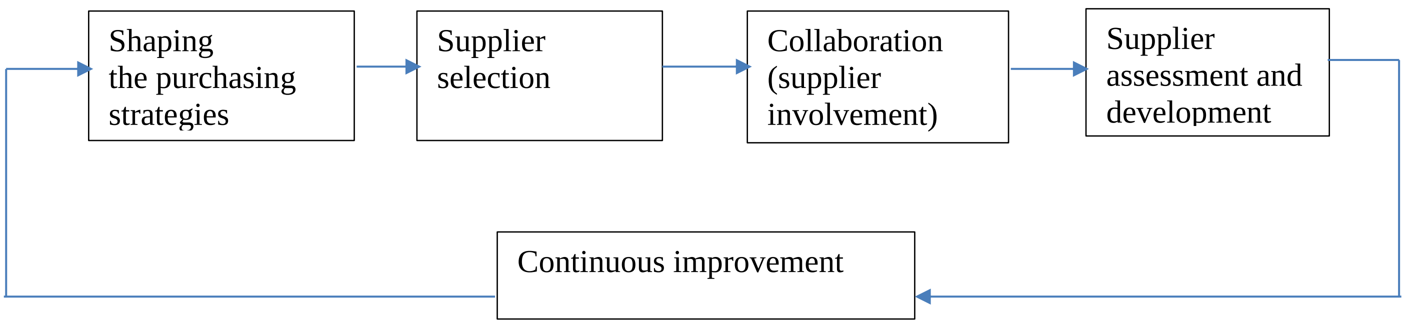


Fig 2.2 supplier relationship framework

- the purchasing strategies by employing the three-step method Step 1 is the classification of the purchasing material by supply risk. Step 2 is the analysis of the supplier relationship, and Step 3 involves the establishment of an action plan. Supplier selection comprised of two phases In Phase 1, a supplier pool is created. In this phase, the suppliers by evaluating them according to criteria such as financial status and technological capability. Phase 2 involves allocating suppliers who supply materials directly, and this step relies on criteria such as cost, delivery, and quality. For a win-win scenario between the supplier and manufacturer, they must share roles and profits through regulation and introduce an advanced method that connects the supplier and manufacturer via shared information.

- The purpose of a supplier relationship assessment is to segment suppliers and to develop suppliers differentially, Continuous improvement (CI) strategy involves the performance of plan-do-check-act (PDCA) cycles based on data in order to continuously improve the system, process, and manpower. It is the strategic activity that causes a company to eliminate pressure from violent competition, reduce cost and time, and improve productivity.

Cooperation in Industry

The activity of an enterprise involves cooperation, both voluntary and involuntary, active and passive, of many and diverse constituents Cooperation between business units is approached on the business relationship level. Business units are economic units, such as e.g. corporations, divisions, national subordinates, profit centers or small and medium-sized enterprises, which are responsible for profits and operate within the market (] J. E. Post, 2002.)

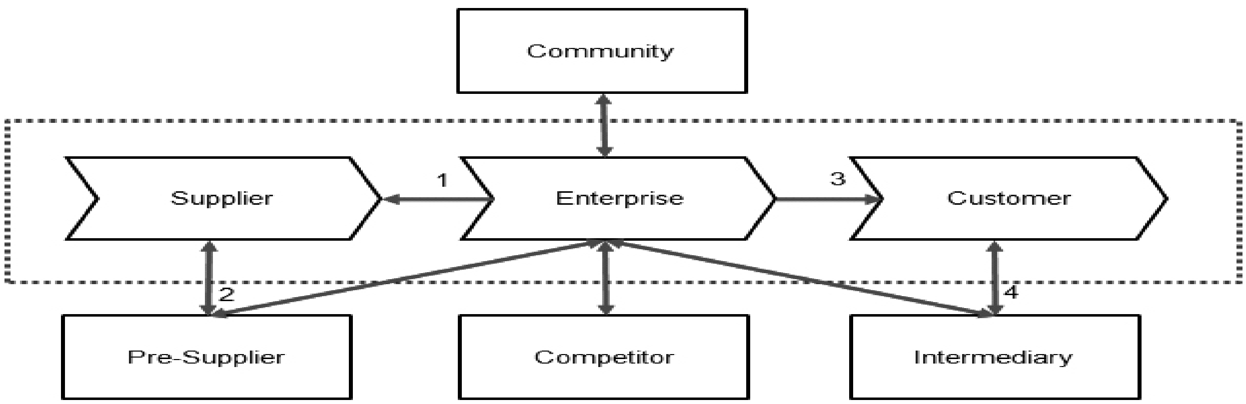


Fig 2.3: Cooperation relationship types

As described above, SRM primarily focuses on the improvement of the relationship between the enterprise and its immediate suppliers (relationship type 1). An enlargement of SRM is the concept commonly referred to as supplier network management (SNM), which also incorporates pre-suppliers (relationship type 2). CRM (relationship type 3) often is seen as the opposite of SRM given that the customers and not the suppliers are in the center of interest (Institute., 2008, July)).

Supplier selection

A good supplier selection process is very important for efficient purchasing and manufacturing. The decision-making process of evaluating and selecting a supplier is complicated for two reasons. First, suppliers can be evaluated by more than one criterion. Second, each supplier has a different specialty and thus a different criterion. Additionally, there are two problems encountered in supplier selection (Ustun and Demirtas, 2008). One is a single sourcing problem: the goal is to satisfy the buyer's needs with one supplier. In this case, the manager must decide which supplier is the best. The other problem is a multiple sourcing problem in which it is not possible to satisfy the buyer's needs with one supplier. In this case, the manager has to choose multiple suppliers and, in turn, allocate supplies to them (Ghodsypour and O'Brien, 1998). the following two issues of the supplier selection approach are paramount:

(1) The identification of which criteria should be considered in the assessment of suppliers (Dickson, 1966; Weber et al., 1991).

(2) The application of techniques for the evaluation of suppliers in the decision-making process so that they can be properly selected (Schniederjans and Garvin, 1997).

Techniques in supplier selection

Obviously, the selection of supplier plays a key role in an organization because the cost of raw material adds the main cost of a final product. Selecting the right suppliers significantly reduces the purchasing cost and improves unified competitiveness. There are various techniques for selecting suppliers/partners, such as mathematical techniques. A comprehensive review of these articles, which have addressed the problem, can be found in (Ghodsypour and O'Brien (2001), which include techniques like linear programming, mixed integer-programming approach, goal programming techniques, multi-objective programming and non-linear programming. Besides mathematical techniques, techniques were used in developing decision support systems for partner/supplier selection (Gupta & Nagi, 1995; Herrmann & Minis, 1996; Minis, Herrmann, Lam, & Lin, 1999).

Functionalities/Areas of supply chain management ((MAKATSORIS, 2006)

Areas of supply chain	**Description**
Demand planning	Demand planning aims to reduce forecast error and to suggest buffers considering demand variability. In order to improve accuracy of forecasting, aggregated forecasting is essential.
Procurement	Constraints such as vendor capacities, costs and lead-times can model as part of supply chain Resulting in superior plans.
Transportation	Consider dynamic transportation requirement and Generate optimizing transportation plan.
Manufacturing	Plan considering material, capacity and other Constraints which influence on manufacturing.

Table 2.1: supply chain functionality areas

Comparison of efficient and responsive supply chains (Marshall L. Fisher,1997**)**

Criteria	**Efficient Supply Chains**	**Responsive Supply Chains**
Primary goal Product design Strategy	Supply demand at the lowest cost Maximize performance at a minimum product cost	Respond quickly to demand Create modularity to allow postponement of product differentiation
Pricing strategy	Lower margins because price is a prime customer driver	Higher margins because price is not a prime customer driver
Manufacturing Strategy	Lower costs through high utilization	Maintain capacity flexibility to buffer against demand/supply uncertainty
Inventory strategy	Minimize inventory to lower cost	Maintain buffer inventory to deal with demand/supply uncertainty
Lead time strategy	Reduce, but not at the expense of costs	Reduce aggressively, even if the costs are significant
Supplier strategy	Select based on cost and quality	Select based on speed, flexibility, reliability, and quality

Table 2.2: supply chain responsiveness

2.4 Redesign Strategies for Food Supply Chain Network

The SCM literature suggests several strategic, tactical, and operational redesign strategies to improve the efficiency and effectiveness of supply chain processes. An extensive literature review by Van der Vorst and Beulens (2002) Identifies a generic list of SCM redesign strategies to facilitate the redesign process and attain joint supply chain Objectives are Redesign the roles and processes performed in the supply chain (e.g., reduce the number of parties involved, reallocate roles such as inventory control, and mitigate non-value-adding activities such as stock keeping). Reduce lead times (e.g., implement information and communication technology (ICT) systems for information exchange and decision support, increase manufacturing flexibility or reallocate facilities). Create information transparency (e.g., establish an information exchange infrastructure in the supply chain and exchange information on demand/ supply/ inventory or work-in-process, standardize product coding). harmonize logistical processes with consumer demand (e.g., increase execution frequencies of production and delivery processes, decrease lot sizes). Coordinate and simplify logistical decisions in the supply chain (e.g., coordinate lot sizes, eliminate human interventions, and introduce product standardization and modularization).

2.5 Supply Chain Performance Measures

The performance measures that have been used in the literature. These measures, and others, may be appropriate for supply chain design and analysis. Available research has not specifically addressed the adequacy or appropriateness of existing supply chain performance measures.

(1) Are the existing performance measures appropriate for supply chains? It is unlikely that a single performance measure will be adequate for an entire supply chain (Beamon 1996). It is more likely that a system or function of performance measures will be necessary for the accurate and inclusive measurement of supply chain systems.

(2) What are the appropriate performance measures for supply chains? what types of performance measures or performance measurement systems are appropriate for supply chain performance analysis, and why?

Supply Chain Optimization

An important component in supply chain design is determining how an effective supply chain design is achieved, given a performance measure, or a set of performance measures. Research in supply chain modeling has only rubbed the surface of how supply chain strategies (or decision variables) may affect a given performance measure, or a set of performance measures. Lee and Whang (1993) and Chen (1997) are examples of such research. Lee and Whang (1993) develop a performance measurement system that tries to match the performance metric of individual supply chain managers with those of the entire supply chain, in an attempt to minimize the total loss associated with conflicting goals. Similarly, Chen (1997) also identifies the relationship between individual supply chain managers and the supply chain as a whole but does so on the basis of inventory costs. In this work, Chen (1997) seeks to develop optimal inventory decision rules for managers that result in the minimum long-run average holding and backorder costs for the entire system.

Optimization Techniques of Supply Chain Network

Network arrangement may involve issues relating to plant, warehouse, transportation, and retailer location. These are strategic decisions since they have a long-lasting effect on the firm. To come up with a better network design, correct number of warehouses, location of each warehouse, and the size and capacity of each warehouse has to be identified and determined. The objective is to design the SC network so as to minimize annual system-wide costs and improve service level requests, thereafter increase market share. Increasing the number of warehouses typically yields: improvement in service level, increase in inventory costs, increase in overhead and set-up costs, reduction in outbound transportation costs, and increase in inbound transportation costs. In this setting, the advantages are clear. (Daniel Kitaw, 2011)

2.6 Transportation optimization techniques

fixed-charge transportation problem (FCTP)

The fixed-charge transportation problem (FCTP) is a mathematical programming problem in which a fixed cost, sometimes called a setup cost, is exposed if another related variable assumes a nonzero value. The problem has a wide variety of classic applications that have been documented in the scheduling and facility location written documents. Two of the most common of these arise in making warehouse or plant location decisions, where there is a charge for opening the facility, and in transportation problems, where there are fixed charges for transporting goods between demand and supply points. (Sadagopan S, 1982)

minimum spanning tree (MST)

minimum spanning tree (MST) problem is a combinatorial optimization problem that appears in many applications such as wire-based communication network design when certain aspects of quality of service have to be considered, in ad-hoc wireless network and in the areas of data compression and distributed mutual exclusion algorithms . (K., 1989) The goal is to identify a tree-structured network of minimum costs in which the number of links between any pair of nodes is restricted by a constant D, the diameter.

Design option for distribution network

When considering distribution between any other pair of stages, such as supplier to manufacturer or even a service company serving its customers through a distribution network, many of the same options still apply. Managers must make two key decisions when designing a distribution network: Will product delivered to the customer location or pick up from a preordained site? Will product flow through an intermediary (or intermediate location)? As stated by (Sunil Chopra, 2007) Based on the firm's industry and the answers to these two questions, one of six distinct distribution network designs used to move products from factory to customer, which classified as follows:

1. Distributor storage with package carrier delivery
2. Manufacturer/distributor storage with costumer pickup
3. Retail storage with customer pickup

2.7 Supply Chain Design and Analysis: Models and Methods

Deterministic Analytical Models

Williams (1981) presents seven heuristic algorithms for scheduling production and distribution operations in an assembly supply chain network (i.e., each station has at most one immediate successor, but any number of immediate predecessors). The objective of each heuristic is to determine a minimum-cost production and/or product distribution schedule that satisfies final product demand. The total cost is a sum of average inventory holding and fixed (ordering, delivery, or set-up) costs. Finally, the performance of each heuristic is compared using a wide range of empirical experiments, and recommendations are made on the bases of solution quality and network structure. Williams (1983) develops a dynamic programming algorithm for simultaneously determining the production and distribution batch sizes at each node within a supply chain network. As in Williams (1981), it is assumed that the production process is an assembly process. The objective of the heuristic is to minimize the average cost per period over an infinite horizon, where the average cost is a function of processing costs and inventory holding costs for each node in the network.

Stochastic Analytical Models

Cohen and Lee (1988) develop a model for establishing a material requirements policy for all materials for every stage in the supply chain production system. In this work, the authors use four different cost-based sub-models.

(1) Material Control: Establishes material ordering quantities, reorder intervals, and estimated response times for all supply chain facilities, given lead times, fill rates, bills of material, cost data, and production requirements.

(2) Production Control: Determines production lot sizes and lead times for each product, given material response times.

(3) Finished Goods Stockpile (Warehouse): Determines the economic order size and quantity for each product, using cost data, fill rate objectives, production lead times, and demand data.

(4) Distribution: Establishes inventory ordering policies for each distribution facility, based on transportation time requirements, demand data, cost data, network data, and fill rate objectives.

Economic Models

Christy and Grout (1994) develop an economic, game-theoretic framework for modeling the buyer-supplier relationship in a supply chain. The basis of this work is a 2 x 2 supply chain. relationship matrix., which may be used to identify conditions under which each type of relationship is desired. These conditions range from high to low process specificity, and from high to low product specificity. Thus, the relative risks assumed by the buyer and the supplier are captured within the matrix. For example, if the process specificity is low, then the buyer assumes the risk; if the product specificity is low, then the supplier assumes the risk.

Simulation Models

Towill (1991) and Towill, et. al. (1992) use simulation techniques to evaluate the effects of various supply chain strategies on demand amplification. The strategies investigated are as follows [38]:

(1) Eliminating the distribution echelon of the supply chain, by including the distribution function in the manufacturing echelon.

(2) Integrating the flow of information throughout the chain.

(3) Implementing a Just-In-Time (JIT) inventory policy to reduce time delays.

(4) Improving the movement of intermediate products and materials by modifying the order quantity procedures.

(5) Modifying the parameters of the existing order quantity procedures.

2.8 Modeling and Simulation

Modeling is an essential process in understanding systems of all kinds. We continually study the behavior of systems by creating mental or conceptual models of them. For example, a model can consist of mathematical equations, procedural rules or graphical processes. The important point is that the model should describe the behavior of some aspect of the system in a precise way. Mathematical models are widely used, for example, in engineering. (Roy Crosbie, 2005).

Needed of Simulation Supply Chain Management

It enables companies to perform powerful what-if analyses leading them to better planning decisions; it permits the comparison of various operational alternatives without interrupting the real system; it permits time compression so that timely policy decisions can be made. Simulation tools aid human planner to make a right decision by providing information. (H. L. Lee, 1997). It helps to understand the overall supply chain processes and characteristics by graphics/animation.

using probability distribution, user can model unexpected events in certain areas and understand the impact of these events on the supply chain. It could dramatically minimize the risk of changes in planning process: By what-if simulation, user can test various alternatives before changing plan. It known that simulation itself does not solve this problem directly, however, we can vary the input parameters of the system and we can observe the changes of the outputs. For example, we vary the value of Reorder point between 50 and 150 units. (MAKATSORIS, 2006)

Performance measure of simulation analysis

Financial performance

Simulation model also records financial performance measures. Direct material, direct labor, and overhead rates considered for assigning costs to each order. All the process costs, including manufacturing costs, applied to orders using predetermined rates along with an overhead rate associated with each activity. (Jeffrey W. Herrmann, September 2-6, 2003)

Delivery Performance

Delivery performance includes the average cycle time at each stage, the overall cycle time, and the percentage of orders that were tardy. For calculating the cycle times, four stages considered order receipt to start build, start build to finished goods inventory, finished goods inventory to release for delivery, and release for delivery to delivery at customer site. The sum of the average cycle times at these four stages gives the overall cycle time. (Jeffrey W. Herrmann, September 2-6, 2003) In this paper delivery performance is the most important point to develop distribution network of the case company.

Inventory Performance

Inventory performance measure is the average of the inventory at the beginning of the period and the inventory at the end of the period. The inventory performance measures include raw material, work in process, and finished goods inventory.(Jeffrey W. Herrmann, September 2-6, 2003)

1. Performance characteristics of Distributor storage with package carrier delivery

Cost Factor	Performance
Inventory	Higher than manufacturer storage. Difference is not large for faster-moving items.
Transportation	Lower than manufacturer storage. Reduction is highest for faster-moving items.
Facilities and handling	Somewhat higher than manufacturer storage. The difference can be large for very slow moving. Items.
Information	Simpler infrastructure compared to manufacturer storage
Service Factor	**Performance**
Response time	Faster than manufacturer storage.
Product variety	Lower than manufacturer storage.
Product availability	Higher cost to provide same level of availability as manufacturer Storage.
Customer experience	Better than manufacturer storage with drop-shipping.

Table 2.3: performance characteristic

2.Manufacturer/distributor storage with costumer pickup

Cost Factor	Performance
Inventory	Can match any other option, depending on the location of inventory.
Transportation	Lower than the use of package carriers, especially if using an Existing delivery network.
Facilities and handling	Facility costs can be very high if new facilities have to be built. Costs are lower if existing facilities are used.
Information	Significant investment in infrastructure required
Service Factor	**Performance**
Response time	Similar to package carrier delivery with manufacturer or distributor storage.
Product variety	Similar to other manufacturer or distributor storage options.
Product availability	Similar to other manufacturer or distributor storage options.
Customer experience	Lower than other options because of the lack of home delivery. In areas with high density of population, loss of convenience may be small.

Table 2.4: performance characteristic

3. Performance characteristics of Retail storage with customer pickup

Cost Factor	**Performance**
Inventory	Higher than all other options.
Transportation	Lower than all other options.
Facilities and handling	Higher than other options. The increase in handling cost at the Pickup site can be significant for online and phone orders.
Information	Some investment in infrastructure required for online and phone Orders.
Service Factor	**Performance**
Response time	Same-day (immediate) pickup possible for items stored locally at pickup site
Product variety	Lower than all other options.
Product availability	More expensive to provide than all other options.
Customer experience	Related to whether shopping is viewed as a positive or negative Experience

Table 2.5 performance characteristic

2.9 General evaluation system of food SCM

Key aim	Drivers & Enablers	Explanation of Key Aims	Logistics System Scope Issues	Literature
Cost reduction	Economic crisis resulting in low prices Globalization resulting in world-wide competition Automation resulting in more efficient processes	The ability to minimize total global network costs from the source of supply to its final point of consumption.	Network design, Distribution channel choice, Outsourcing, Operational excellence, Inventory positions choice, Transportation alternatives and constraints, Production choices, Incorporation of uncertainty, Use of information technology.	(Beamon, 1998) (Cachon and Fisher, 2000) ,(Christopher and Juttner, 2000) ,(Chopra, 2003) ,(Chopra and Meindl, 2010), (Fisher, 1997) , (Gunasekaran*et al.*, 2008), (Lambert and Cooper, 2000) , (Simchi-Levi *et al.*, 2009)
Improved responsiveness	Demand for more product variety, high frequent deliveries with short lead times and small batches Increased demand uncertainty New ICT tools that facilitate more advanced information exchange	The ability to have a flexible and robust system that satisfies customer orders in time and responds quickly to the dynamics of the global marketplace. Additionally, to cooperate and collaborate with the other supply chain members in a way that facilitates movement of information in timely, reliable and accurate manner.		
Improved food quality	Demand for safe and high-quality food products Health consciousness of consumers Year-round availability of food	The ability to control product quality in the supply chain and deliver high quality food products in various forms to final consumers by incorporating product quality information in logistics decision making.	**All the above +** Dynamic inventory management, Dynamic control of goods flow, Cold chain management, Multiple temperature consideration for multiple products, Product interferences consideration, Monitoring temperature history,	(Akkerman*et al.*, 2010) (Blackburn and Scudder, 2009), (Dabbene*et al.*, 2008) ,(Hafliðason*et al.*, 2012) ,(Trienekens and Zuurbier,2008) ,(Van der Vorst *et al.*, 2000) ,(Van der Vorst *et al.*,2007)

Table :2.6 key aims of food supply chain

2.10 Summary table

Author	Method	Title	Finding
(Sabri, 2000)	A Multi Objective Approach	A Multi-Objective Approach to Simultaneous Strategic and Operational Planning in Supply Chain Design	This research developed a supply chain model that facilitates simultaneous strategic and Operational planning using an iterative method.
(Spekman, 1998)	empirical investigation	An empirical investigation into supply chain management	The results suggest that business has not yet operational the concept of supply chain management.
(H. KRIKKEy, 2003)	Concurrent product and closed-loop	Concurrent product and closed-loop supply chain design with an application to refrigerators	Supply chain network structure has most impact on costs, whereas the product design has most impact on energy and waste.
(Kenneth J. Petersena, 2005)	multiple regression analysis	Supplier integration into new product development: coordinating product, process and supply chain design	emphasize the criticality of the supplier selection decision in this type of effort, considering not only the capabilities of the supplier, but also the culture of the supplier, which will have an impact on the buying firm's ability to interact with the supplier effectively.
(JayshankarM.swamintham, 1998)	multi agent approach	Modeling supply chain dynamics, a multi agent approach	Simulation based frame work for developing customized supply chain models from a library of software components
(June Young Jung a, 2004)	A simulation-based optimization approach	A simulation-based optimization approach to supply chain management under demand uncertainty	Determine the safety stock levels for planning and scheduling applications involving realistically scaled supply chains, which have the various complex characteristics arising in Typical chemical process companies.

(Brinzaa, 2012)	Simulation	Simulation and optimization in Supply Chain	Good weather is going to have a significant impact on sales as compared to a rainy and cold day. Adding weather as an independent factor would have absorbed much more of the variation out of the current model and lead to a more accurate demand forecast.
(Gábor Belvárdi1, 2012)	simulation	Monte Carlo simulation based Performance analysis of supply chains	Authors introduce an interactive simulator, SIMWARE that is capable to simulate complex multi-echelon supply chains based on simple configurable connection of building blocks. To support the evaluation of the extracted gradients (sensitivities) a simple Visualization technique is developed.
(Hartl, 2009)	Simulation and optimization	Simulation and optimization supply chains: alternative or complementary approaches.	In many cases, the SimLP method seems to be a good trade-off between solution Quality and computational time. If the nonlinear elements in the model are Dominating, it is better to apply the SimMIP approach and consider these nonlinearities in the optimization model as long as the computational time for solving the optimization model is acceptable.
(MAKATSORIS, 2006)	simulation	Supply chain modeling using simulation techniques	Review the benefits, functionalities and data requirement of the supply chain, which needed to prepare for the modeling of supply chain simulation.

Table 2.7: literatures summary table

2.11 Literature Summary and gap

There are different published and unpublished literature's those are related with supply chain system network development, performance analysis, simulation analysis and Ethiopian wheat value chain documents are used to further purify the research paper. Some research documents explained about; assessment of the degree of vertical price transmission along the wheat-bread value chain in Ethiopia. This accept by applying a vector error correction model (VECM) and an impulse response analysis using monthly price data for the period 2000 –2015. The empirical results indicate that significant co integration exists across prices of the different stages along the value chain.

Some researches Deal with customer-oriented issues. For example, a customer's demand may not be fully satisfied from stock on hand and the shortage may be the sale may be lost. Either way, it is desirable to balance the holding cost depends on the size of inventory against the cost of not fully satisfying customer demand. Modelers typically focus on the following key performance measures, which eventually can have translated to monetary measures: customer service levels (the rate of very satisfied customer demands), average inventory levels and backorder levels, rate and quantity of lost sales and inventory cost.

Supply chain performance improvement methods also describe supply chain simulation framework that follows the Supply Chain Operations Reference (SCOR) model. This framework used for building best simulation models that integrate discrete event simulation and spreadsheets. The simulation models are ranked and use sub models that capture activities specific to supply chains. The SCOR framework provides a basis for defining the level of detail in a way as to include as many features as possible, while not making them industry specific.

wheat is one of the challenging agriculture sector in Ethiopia some researchers also tries to identify factors affecting supply issues at different functional nodes of Wheat Value Chain (WVC), flow of commodities and roles of cooperatives and other institutions in supply issues. Most of researchers made an agreement simulation is the most power full tool to improve the performance of supply chain system and discusses issues of supply chain management and the requirements for supply chain modeling.

In a today's highly competitive market manufacturers face the challenge of reducing manufacturing cycle time, delivery lead-time and inventory reduction. However, every company has its own objectives and its own way of decision-making processes. Due to the misunderstanding among the objectives of each organization and non-integrated decision-making processes, there has been a need for some new ways, which help to resolve those conflictions and to integrate processes.

However, this research attempt to add some knowledge about supply chain system simulation analysis technique on Ethiopian wheat flour sector by taking KOJJ food complex as a case. As far as my literature review, most of the researches focused on single hub system simulation but this research attempt to simulate the whole supply chain system from suppliers to customer. The other point is the researches are does not clearly shows the effect of simulation technique by taking examples of real supply chain case versus the simulated one. And also researches done in Ethiopian wheat sector focused on value addition areas and they describe the existing problems by using exploratory form of research, but they didn't analyze those factors.

CHAPTER THREE: RESEARCH DESIGN AND METHODOLOGY

3.1 Literature Survey

For the analysis of supply chain, a system different type of techniques is identifying by referring various articles, books and thesis. In addition, building of supply chain Network Process model initially involves collecting all factors that affect the effectiveness of supply chain system collected from literature with interrelation between them found through interview, observation and using appropriate questions.

Research Approach:

Mixed approach: the research uses Qualitative and quantitative data type Respondents are interview face to face at random across the study area which is represented from the company different departments, suppliers, customer's, government authorities and expertise. In addition, the questionnaires will distribute across each representative.

3.2 Data collection techniques and tools

Primary Source

- Data collected by researcher himself through, interviews, questionnaires and Observations. transportation rates, warehouse costs, and service level requirements, in addition in developing inventory model, problem identification and supply chain network design needs (Physical observation, preparing informal interviews and questionnaires related to the work, Discussion with employees) will be conducted.

Secondary sources

- Data collected, compiled or written by other Researchers any acknowledged reference would be included. different literature's state their supply chain management strategies to develop supply chain network, the study uses those literatures to explore basic concepts and scenarios about supply chain.

Data collection

Research participants and main themes identified			
Data collection method	**Unions and cooperatives**	**Processors (company)**	**Customers/whole sellers**
survey/Interview/ questionnaires	Quality of wheat produced, Mechanization use, Wheat price, Value addition	Milling capacity, Quality and quantity of wheat supply, Capacity utilization, Supplier r/ship, distribution system, supply chain management,	Quality of wheat flour produced, Market information, availability of product and delivery

Table 3.1 data collection methods

Measurement variables

the measurement variables for supply chain network the basic set of message classes the type of interaction that can takes place within the network. All message classes share a specific attribute common including the simulated agent. (JayshankarM.swamintham, 1998) Therefore, it categorizes three massage classes that flow with in the supply chain.

Material flow variables Manufacturing process and time information Processing time, setup time, no of machine, shift, holiday, maintenance, bill of materials. Unloading raw material to the company, Input material**,** finished goods, Shipped goods from company to customers

Information flow Demand information Incoming orders from customers, ordered placed by the company from suppliers, Suppliers on hand capacity, Due date, start and end data, demand pattern, Safety stock level, reorder point, finished goods, WIP, raw material

Fund flow variables Inventory Cost, Backlog Cost, Transportation cost

3.3 Research design

Research population

The target population of the research is representatives from the case companies' different departments, experts who has specialized knowledge on agriculture area, wheat value chain actors like seed multipliers, farmers or farmers unions and cooperatives and final customer, distributor's, whole sellers are participated. the population of the study will be **175** participants, which selected from suppliers are 28 unions from Arsi and bale farmers union which are taken all taken, the case company has 47 employees and from consumers/whole sellers that are work with the case company and customers of the company is 100.

Sampling technique

Simple Random Sampling

The logic behind simple random sampling is that it removes bias from the selection procedure and should result in representative samples. Under simple random sampling the study, using solvin's formula to estimate sample size (n).

Sample size (n) is computed as:

$$n = \frac{N}{1+N(e)^2}$$

whereas: **n** = no. of samples, N = total population, **e** = error margin / margin of error Confidence level of 95 present (which will give us Margin of Error of 0.05),

After calculating each population to decide the sample size there will be 150 participants selected for data collection process. Out of 150 sample 130 questionnaires will be distributed and 20 interviews conducted by selecting randomly from each respondent.

Sampling criteria

Suppliers (28 respondents)	Processors (42 respondents)	Customers (80 respondents)
Unions/ cooperative offices	Case company administration	whole sellers/retail stores and shops
Experts on the sector	Case company employers	high users of wheat flour
Agriculture offices	Case company competitors	company trusted customers

Data analysis and presentation

After collecting all information needed for the research, the data analysis and synthesis carried out. To make the qualitative analysis more accurate and efficient an IBM SPSS software package used to generate tabulated reports, charts, and plots of distributed and trends, descriptive statistics analyses of the collected questionnaire. And also, quantitative data related to transportation, distribution and inventory management model imputes will be collected to develop quantitative analysis about the existing supply chain network of the company through survey, considering the recorded data's and company daily monthly and annual reports. Moreover, simulation analysis will be conducted for evaluate the performance of supply chain system of the company by using ARENA simulation software to generate different simulated results.

Reliability and Validation

In this paper the validation process conducts to determines that the simulation is a most appropriate representation of the real system from the perspective of the intended use of the physical model or simulation. Therefore, the simulation model coded and debugged systematically. The simulation trial runs under a variety of settings of the input variables and checked the model output results for its appropriateness.

CHAPTER FOUR: SECTOR OVERVIEW

In Ethiopia, both the bread and durum wheat are widely grown in the highlands of the country largely in the areas like South East, Central and North West parts. According to MoARD (2005), it estimated that 1.4 million hectares of land is covered with wheat and more than (FAO 2015b) 3.9 million tones are produced in 2013/2014 by close to 5 million small holders farmers, about a third of all smallholder farmers in the country (CSA, 2014). After south Africa, Ethiopia is the second largest wheat producer in sub-Saharan Africa. In terms of area cultivated and annual production, wheat is the third most important cereal crop in Ethiopia following maize and teff (CSA, 2012).

Wheat is mostly growing in the highlands and mid highland area of the country**.** Among the nine regions, Oromia and Amhara regions produce 59% and 27% of the country's wheat, respectively, with an additional 9% coming from the Southern Nations, Nationalities, and Peoples Region (SNNPR). Nearly around 98% of cereals are produced by small holder farmer, while 2% is produced by commercial farms mainly for seed multiplication purpose.

Wheat Production and market flow map

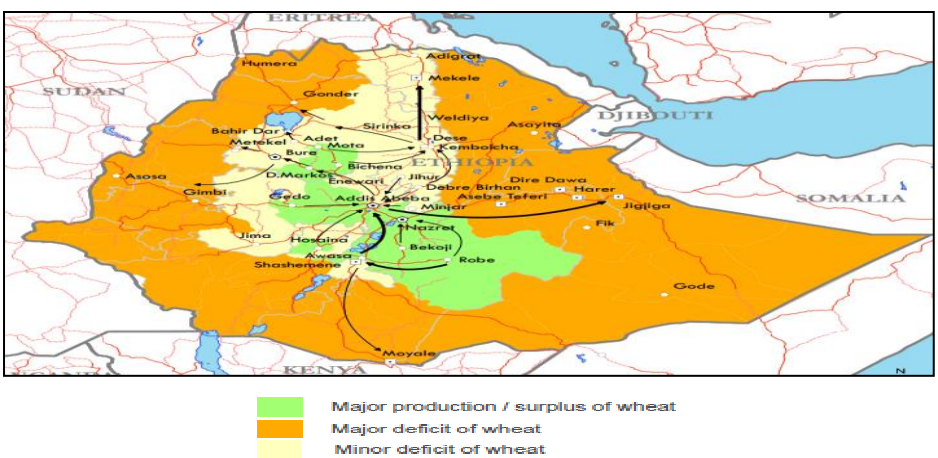


Fig 4.1: areas of wheat production in Ethiopia

- 91% of wheat sale transactions took place at local markets Cooperatives play a negligible role in marketing - minimal amounts of wheat transactions took place at cooperatives.75% of wheat sales are to traders and wholesalers 15% are sold directly to consumers, ~7% to other farmers, and <1% are sold to Cooperatives.

Source: FEWSNET, Context Network stakeholder interviews and analysis

Ethiopian millers' association report

- Total number of active Mills in EMA (Ethiopian mill association) There are about 210 flour mills in Ethiopia, with a total production plant capacity of 3.2 million tons of flour a year.

Operational Density %

- 51% in Oromia Region
- 22% in Southern Region
- 17% in Addis Ababa
- 10% in other Regions
- Current Total Flour Milling Capacity is 10,858 ton/day (2,996,808 ton/year)

Source: Ethiopian Millers' Association Flour Milling, Pasta & Biscuits July, 2015 AbebaTesfye EMA, Vice President

Wheat production, import and self-sufficiency in Ethiopia

Year	Wheat Production (million tons)	Wheat Import (million tons)	Estimated marketable surplus* Share of imported wheat	As total Domestic production (%)	As domestic surplus/marketable Production (%)
2012/13	3.43	1.64	0.686	47.8	191.3
2013/14	3.93	1.62	0.786	41.2	164.9

Table 4.1 wheat import

Source: Computed based CSA (2015c) and FAOSTAT (for data on wheat import).

Global import and domestic wheat prices

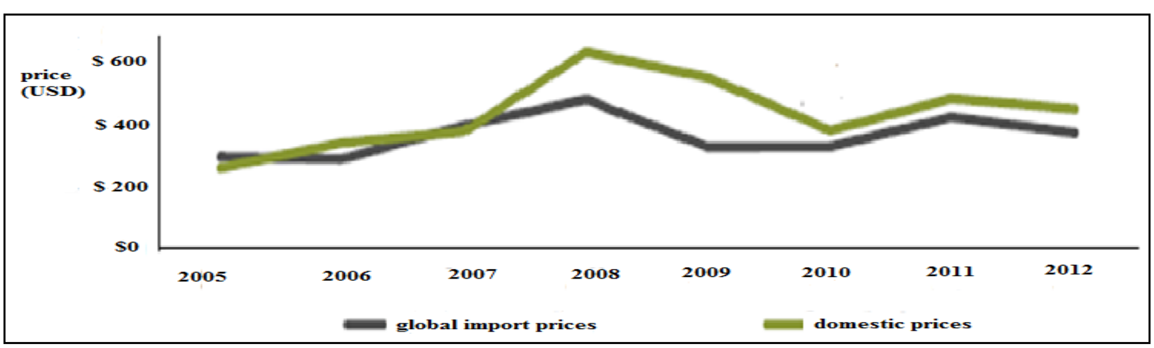


Fig 4.2: global import and domestic wheat price

Source: UNCOMTRADE, USDA Ethiopian Grain and Feed Annual report

Total wheat imports in Ethiopia

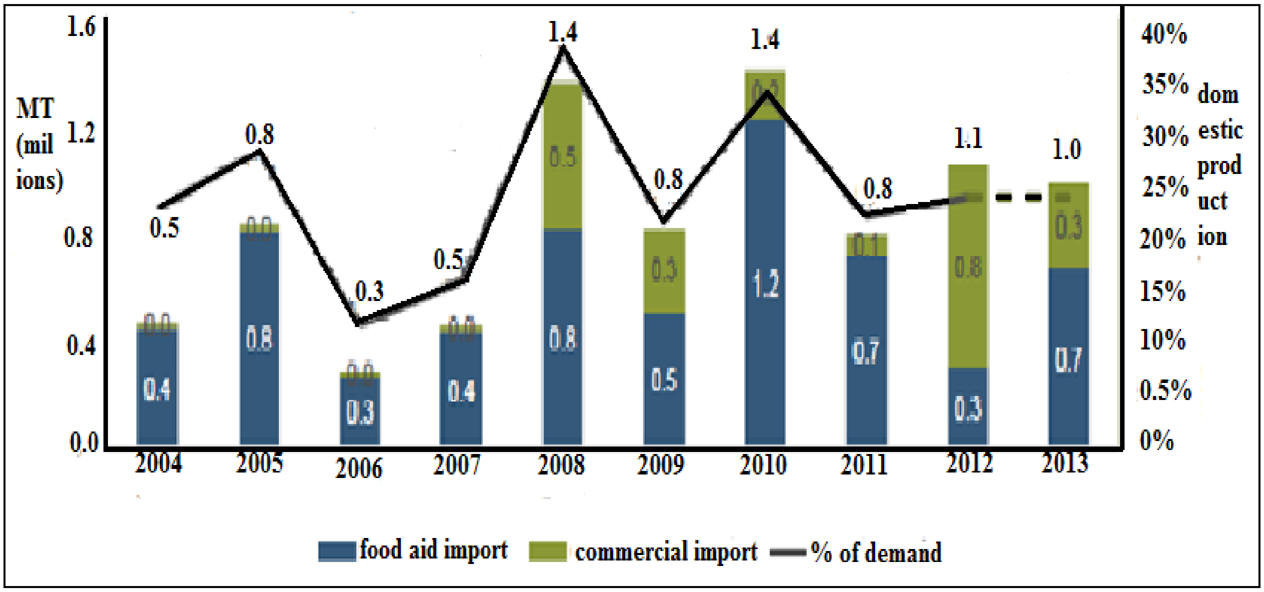


Fig 4.3: Ethiopian total wheat import

- Interviews suggest 65% of imported commercial wheat is durum wheat in recent years, which is primarily used for pasta production

Source: UNCOMTRADE, USDA Ethiopian Grain and Feed Annual report

Actors in wheat value chain

Service providers: NGOs and private enterprises support actors to transact wheat and render various services such as input supplies (seeds, fertilizers, pesticide and herbicide, tractor and combine harvester), trainings, market information (prices, buyers, and suppliers), financial services (such as credit and savings). However, all value chain actors do not always get these services consistently and timely.

Wheat producers: They sell wheat to downstream actors such as assemblers, WPI, wholesalers, and end users. About 80% of wheat market surplus is sold to wholesalers at farm gate, warehouses and spot market.

Wholesalers: Wheat processing industries distribute wheat products to wholesalers and retailers through their agencies throughout all locations.

Cooperatives: Unions provide limited amount of money to basic cooperatives in form of debt. They stick to blue print approach that takes away their input and output market decision power. Thus, they were limited to purchase only 25,074.17 quintals of wheat per annum from farmers at spot markets and cooperative offices in Gimbichu district, 13,792.36 quintals of wheat in Hetosa region and 782.29 quintals of wheat in Tiyo district.

Wheat processing industries (WPI): Wheat goes through different sectors and activities with significant value addition before it reach final consumers. They sell former one to wholesalers and retailers at market price and distribute later one to bakeries at subsidized fixed price. Specifically, WPI purchase about 80% of raw materials from wholesalers, 10% from government quota wheat, and 10% directly from farmers.

Milling: A number of milling provider services found in Hetosa and Tiyo districts, which milled on average 8 quintals of wheat per day and 15 quintals of wheat per day in Chefedonsa town for urban and rural consumers.(Zewdie Habte, September2016)

Projected Supply and Demand in Ethiopia through 2030

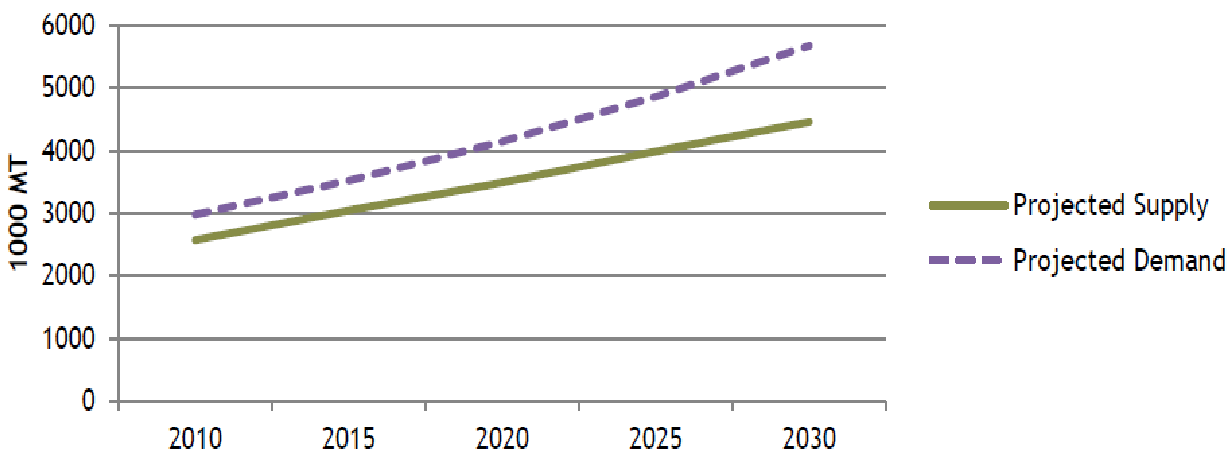


Fig 4.4: future wheat supply and demand

Demand for wheat is projected to continually exceed supply from 2010-2030 and the gap will grow slightly more pronounced moving toward 2030. In 2015, the gap between expected supply and demand expected to be over 400 thousand tons. By 2030, the demand-supply difference expected to exceed one million tons.

Source: IFPRI impact Projections

4.1 Case Company

K.O.J.J FOOD PROCESSING COMPLEX is the family owned and operated business established in 2002 in Addis Ababa Ethiopia. The company is known high quality wheat flour, wide variety of biscuits, pasta and macaroni products. The wheat flour (85-90% of its production) has been the core business of K.O.J.J. the flour milling capacity is 140 tons/day and the source of major raw material (wheat) is locally here in Ethiopia. Within the 14 years of biscuit making, it has made a significant impact on the competitive biscuits industry. One of the top KOJJ biscuit factory technologies has in the industry and currently one of the leading products in biscuit market. Even though KOJJ is new to the market for pasta and macaroni it become rapidly preferable than its competitors like flour and biscuits lines. Also, in the technology advancement area, the company applying in all products advanced technologies. The quality of KOJJ production based on a careful selection of wheat supported by highly equipped laboratories and the mill supported by motivated and highly qualified staff with hard working personnel.

Mission

- Build long-term relationship with its domestic and international customers by delivering the high standard products.

Vision

- Be the leading food processing company in Ethiopia.

Source of raw material

- Bale
- Gojam
- Arsi

Product variety

- Sarem biscuits
- Pasta
- Macaroni
- Wheat flour

Competitors

Name of the company	Capacity /year	Location
Alhamdu flour plc	30,000 ton	Burayu
Kaliti food share company	39,886 ton	A.A Kaliti
Afia food processing	25,000 ton	Burayu
Nas foods factory plc	20,000 ton	Legetafo
Misrak flour & bread factory	22,061 ton	A.A gotera
Fafa food share company	14,314 ton	A. A saris

Table 4.2 competitors

Wheat flour production flow process diagram

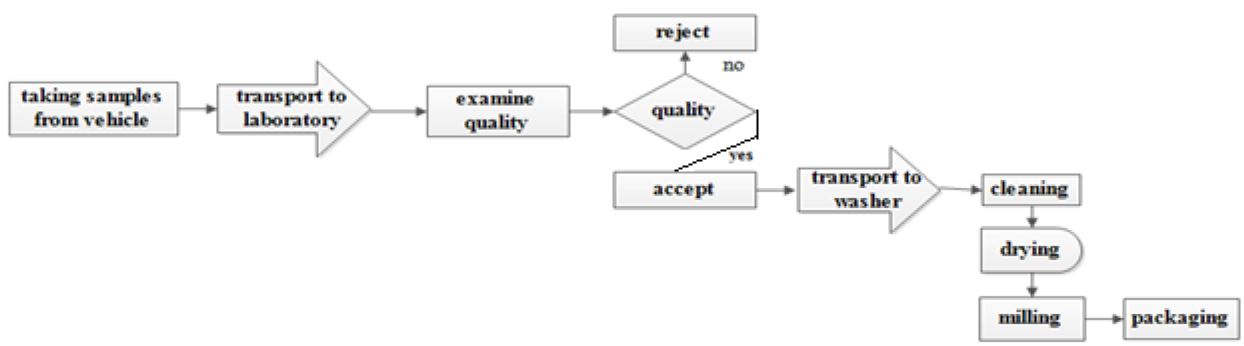


Fig 4.5 production flow process

4.2 existing company supply chain network

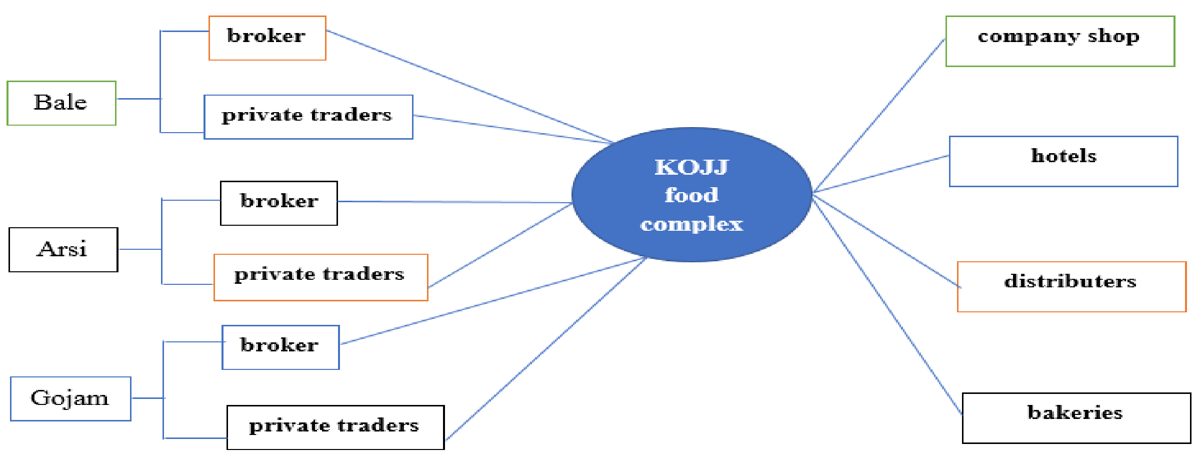


Fig 4.6: existing supply chain of the company

CHAPTER FIVE: DATA COLLECTION AND ANALYSIS

5.1 qualitative data analysis

5.1.1 Suppliers

From 130 distributed questionnaires about 98% is collected and 100% interview is conducted. generally, out of 150 respondents 147 respondents are participated.

Farmers' perception about industrial wheat quality requirement

During survey, about 72.7% of respondent growers have enough awareness about key variety characters including bread baking quality standards that are important required within the wheat milling processing industries. a decision to plant farmer's own fields with wheat seeds for the season not carefully thought in favor of potential customers (flourmill factories) bread baking quality preference. Rather it is dependent on farmers' will and perception, whether there is an easy access to get credit to buy the required seeds, and access or availability of seed from last year's harvest, or simply recommitment decision to plant an adaptable variety to farmer's specific growing environments.

Wheat farm cultivation, planting and storage methods for industry requirement

From the survey, the researcher was aware of the fact that the majority of farming and planting activities for growing wheat carried out using labor, which is followed, by a pair of oxen power and tractor to cover seeds with the soil. In addition, from the sample survey. Cultivation and planting methods needs to be improved to supply the intended quality for the milling factories

Improved Bread wheat seed

About 95% sample respondents from the survey have indicated higher interest for an improved seed source but now 59 percent of suppliers use accepted (certified) seeds. This implies that wheat producers generally prefer improved seed varieties compared to local seed to attain higher productivity per unit area. But still there is a problem of supplying enough quality raw materials the milling factories, therefore the farmers should turn their face good quality wheat seeds to increase their supply capacity as well as their productivity.

Price fluctuation of wheat cost from (Arsi and bale unions survey)

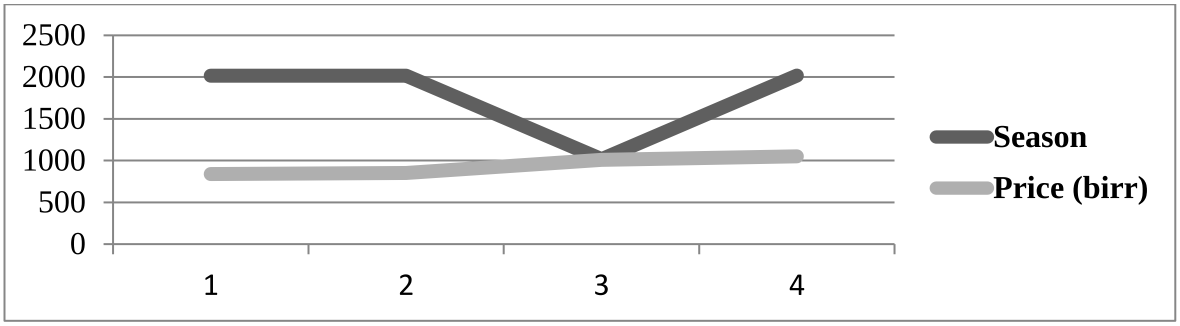


Fig 5.1 price fluctuation

5.2.2 Processors

The questions mainly focused supply chain management system of the company. According to the questionnaires, also try to include lower level workers up to the higher management. the responses explained in detail below: The main raw material they use is wheat, because the main product of the company, which is more than 85%, is wheat flour. The other products are new for the company and produce in low volume. The source of raw material mostly from bale, Arsi and Gojam but mostly their monthly raw materials depend on market demand and consume 38000 quintals/month.

Supplier relationship issues

The Company has no relationship with the wheat producer/farmers. Instead, brokers and merchants contact with farmers and select quality/demanded wheat and deliver to the company then the company evaluates the quality and buy from them. However, in supply chain, the company not work with the farmer to improve the performance and quality related issues. 95 % of respondents are stated that they have no suppliers/farmers relationships.

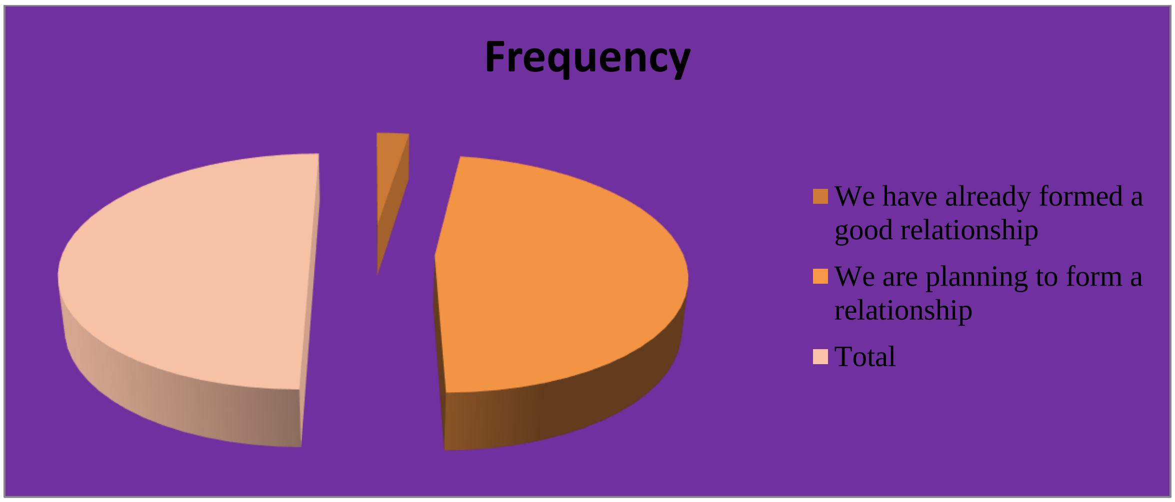


Fig 5.2: supplier relation ship

Companies' location and facility for production and product distribution

The setup of the company has different problems related to infra structure, power, raw material availability, distribution, and external problems.75percentage of companies working in under difficult conditions. The companies' competitor strategy is" first for quality" they believe if the product has been consistent and attain at high level. They can beat their compotators as well as expand their market share. Here of they have working on 90% of their manufacturing process by selecting high quality wheat/raw material selection process.

Below production capacity

The Milling industry manufacturers are producing very much below their machine capacity, which ranges between 20 to 25 % of their machine. The major reason is less supply of wheat, which meets the specification requirements for flour, pasta, macaroni, and other related wheat products. Moreover, power supply, water and other infrastructure problems have been also contributing to low production capacity even when the supply of wheat is available.

Brokers

Excessive interference of Brokers' roles in minimizing the transaction costs of search and information. Poor and unreliable grading and standard system creates loopholes for excessive intervention of brokers. Also creating suppliers distorted information highly influences the supply chain of the flour sector. Generally, there are different kinds of problems are stated by the companies which is related to the supply chain of the wheat sector. Here is the summary of the raised problems: Traders and brokers mix some unwanted impurities to high the weight of each package, Different standard and inconsistent quality of raw materials, Shortage of durm wheat (hard wheat) and shortage of wheat in general, Inconsistent supply of wheat from government, Highly fluctuating price of raw material, Facility problems like power, water, infrastructure…etc.

Quality related issues

As stated on the problem statement the faces frequently quality problems on raw material, which is about 2-3%/kg of unwanted impurities.

Cost analysis of this problem

Supply wheat/month	
KOJJ Asco branch	**Sarem (KOJJ Burayu branch)**
732 tons	668 tons
602 tons	698 tons
1066 tons	34 tons
Total 2400 tons/month	1400 tons/month

Table 5.1: cost of raw material

Metrics: 1kuintal=100kg

: 1ton=10kuintals

: 1ton =1000kg

2.5% of 100 kg =2.5kg

2.5 * 10 = 25 kg/ton

- Therefore: Average cost of wheat/quintal from suppliers is 1050birr; the company monthly demand is 3800 tons/month and according to the above calculation the company receive25kg of unused impurities per ton,

1ton = 25kg

3800ton = x

$$x=\frac{3800ton*25kg}{1ton}$$

x=3800kg

- The total cost of the company loss due to quality problem per month is 38kuintals * 1050=39,900birr/month.

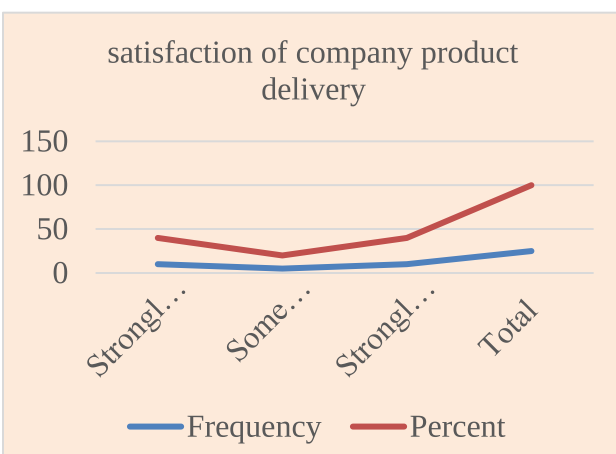
According to the above cost analysis the company loss much money because of low quality wheat, according to the researchers survey the cause of the problem of comes from different areas like:

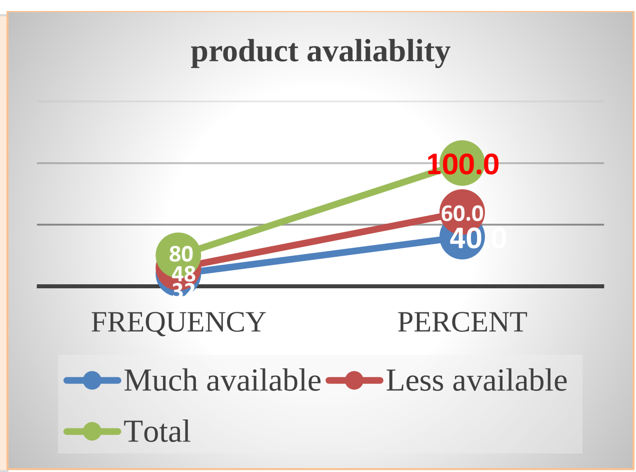
1. **Harvest to storage**: Because of transportation equipment or system, the wheat will expose to additional impurities, and improper storage will affect the quality.
2. **supplier relationship**: the main need for trusted supplier relationship is to makes supplied materials will be according to the companies need can be realize because of long period relationship, but some suppliers add unwanted impurities to increase the weight of the supplied raw material.
3. **Inventory management problems**: sometimes the company holds high inventories to manage the coming shortages of raw material because of this the raw materials store for longer periods and exposed to sand, moisture and other impurities.

5.2.3 Customers

Product Distribution and availability

According to the survey, the company has a shop around the company, which is only kolfe keranio subcity. Moreover, there is no alternative shop around Addis Ababa city; also, there are any satellite stores to manage the shortage and distribution of the product. In addition, product availability is the critical problem of the company.





Delivery status of the company

availability of company product (wheat flour)

Fig 5.3 distribution complaint of customers

The company has wide customers for wheat flour around Addis Ababa but the potential customers are: Hotels i.e. Sheraton Addis, Hilton, elile, intercontinental…Restaurants, Burger house and bakeries. The company distributes the wheat flour only in Addis Ababa because of the capacity of the company.

Quality of the product

The company competitor strategy is" first for quality" they believe if the product has been consistent and attain at high level. They can beat their compotators as well as expand their market share. Here of they have working on 90% of their manufacturing process by selecting high quality wheat and the company is ISO; 22000; 2008 certified because of producing healthy product for human being.

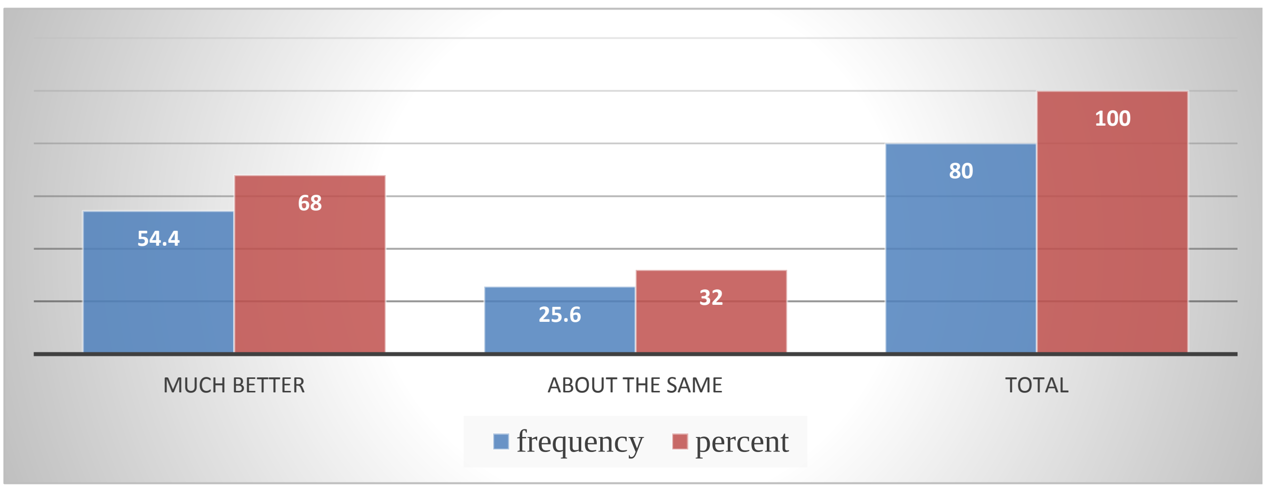


Fig 5.4 product quality

General supply chain system of flour

Wheat flour has a bit higher numbers of marketing channels than any other cereal crops. It passes through different nodes in its way to reach the ultimate consumers. The volume of wheat flown in to the market and end receiver within the channels meaningfully differs for each channel. However, identified and possible wheat marketing channels looks like as listed below.

1 producers-consumer

2 producers- cooperative/union-processor-consumers

3 Producer-cooperatives/union-processor-institutions

4 producers-cooperative/union-processor- urban wholesaler-hotel/restaurant

5 producers-cooperative/union-processor-urban wholesaler-supermarket-consumers

6 producers-assembler-rural wholesaler-processor-urban wholesalers-hotels/restaurants

7 producers-assemblers-rural wholesalers- processor -urban wholesaler-supermarket-consumer

8 producers-assemblers-rural wholesaler-processor-urban wholesaler retailers-consumers

The number of the mills in the country according to survey. With high production capacity, these mills supply a part of the wheat they need with imports via government agencies and supply another part from the domestic market. Still the market is not satisfied there is high demand from customers with in the country. The other point related to the market is high interest on investing in the sector but because of the shortage of input some companies abandoned and turn their face to other sectors, the implication behind this problem there is low production of wheat, low agricultural technology advancement, less plough land and other problems related to certified and standardize seeds…etc.

5.2 Quantitative data analysis

5.2.1 Raw material supply

From the above information each supplier supplies different tons of wheat to the company, for our research optimization process we can take the minimum amount of supply from each source to determine their minimum capacity of supply to the company. From bale their maximum capacity supply to the company is 1413 tones/month and minimum of 1400tones/month within 16 months, it implies that the supply can supply minimum of 1400tones wheat per month for both companies. Similarly, the other sources Arsi (max 1320tnes/month min 1300 tones/month) and Gojam (max 1135tones/month, min 1100tones /month).

Therefore, the information summarized in table below

Suppliers	**Total Supply/month**	**Supply wheat/month**		**Transportation Cost**	
		Asco branch	**Burayu branch**	**Asco branch**	**Burayu branch**
1. bale	1400ton	732 tons	668 tons	700 birr/ton	715 birr/ton
2. Arsi	1300ton	602 tons	698 tons	550birr/ton	575 birr/ton
3. Gojam	1100 ton	1066 tons	34 tons	1100 birr/ton	1115 birr/ton

Table 5.2 raw material supply to the company

The existing transportation cost of the company

= 700Xa1+715Xb2+550Xa2+575Xb2+1100Xa3+1115Xa2

= 700 (732) + 715(668) + 550 (602) +575(698) +1100(1066) + 1115(34)

= 2,932,980 birr/month

Transportation optimization methods

Suppliers	**Supply/year**	**Supply/month**	**Transportation Cost**	**Time**
1. bale	16,800 ton	1400ton	700 birr/ton	16 hr.
2. Arsi	15,600 ton	1300ton	550birr/ton	8 hr.
3. Gojam	13,200 ton	1100 ton	1100 birr/ton	12hr
Total demand /year	45,600			

Table 5.3: transportation data

Mill demands the following number of tons of wheat per month. Asco branch 2400tons/month and Burayu branch 1400tons/month.

The cost of transporting one ton of wheat from each supplier (source) to each mill (destination) differs according to the distance and vehicle system. These costs are shown in the following table. For example, the cost of shipping one ton of wheat from the supplier at bale to the mill at Asco branch is 700birr/ton.

	Mill company	
Suppliers	**Asco branch**	**Burayu branch**
Bale	700birr/ton	715birr/ton
Arsi	550birr/ton	575birr/ton
Gojam	1100birr/ton	1,115birr/ton

Table 5.4: transportation cost

The problem is to determine how many tons of wheat to transport from each grain elevator to each mill on a monthly basis in order to minimize the total cost of transportation. The linear programming model for this problem formulated in the equations that follow:

Minimize Z 700x1a + 715x1b + 550x2a + 575x2b + 1100x3a+ 1115x3b

Subjected to

X1a +X1b=1400

X2a + X2b=1300

X3a + X3b =1100

X1a + X2a =2400

X1b + X2b= 1400

Xij>=0

Vogel's Approximation Model

Destination A, can be supplied by Bale, Arsi, and Gojam. The best decision would be to supply Arsi from source 2 because cell 2A has the minimum cost of 5500birr. If a wrong decision was made and the next higher cost of 575 was selected at cell 2B, a "penalty" of 25birr per ton would result. This demonstrates how the penalty cost is determined for each row and column of the tableau. The general rule for computing a penalty cost is to subtract the minimum cell cost from the next higher cell cost in each row and column.

To / from	A (Asco branch)	B (Burayu branch)	Supply	
1	700	715 1400	**1400**	**= 15**
2	550 1300	575	**1300**	**=25**
3	1100 1100	1115	**1100**	**=15**
Demand	**2400**	**1400**	**3800**	
	=150	**= 140**		

Table: simplex table

The transportation cost of this solution computed by substituting the cell allocations (the amounts transported)

X2a=1300

X3a=1100

X1b=1400

Into the objective function

Z= 550X2a + 1100X3a + 715X1b

= 550(1300) + 1100(1100) + 715(1400)

= 715000 + 1,210,000 + 1,001,000

= 2,926,000 birrs

Therefore, minimum cost method and Vogel's approximation methods have the optimum solutions. Once an initial basic feasible solution determined by any of the previous three methods, the next step is to solve the model for the optimal (i.e. minimum total cost) solution.

The Stepping-Stone Solution Method

Our first step in the stepping-stone method is to evaluate these empty cells to see whether the use of any of them would reduce total cost. If we find such a route, then we will allocate as much as possible to it.

To / from	A	B	Supply
1	- 700 1100 +	+ 715 - 300	**1400**
2	550 1300 -	575 +	**1300**
3	1100 +	1115 1100 -	**1100**
Demand	**400**	**1400**	**3800**

The transportation cost of this solution is computed by substituting the cell allocations (the amounts transported)

=575-715+700-550=+10

=1100-700+715-1115=0

- Therefore, there is no negative value, which means this the only optimum solution for the existing transportation scenario.

Modified distribution method (MODI)

		V1=700		V2=715		
	To / from	**A**		**B**		**Supply**
U1=0	1	1100	700	300	715	**1400**
U2=-150	2	1300	550		575	**1300**
U3=400	3		1100	1100	1115	**1100**
	Demand	**2400**		**1400**		**3800**

The cost changes for the empty cells now computed using the formula

Cij - ui - vj = kij:

=700-700-0=0

=715-715-0=0

=550-(-150)-700=0

=1115-400-715=0

- Because none of these values is negative, the solution shown in Table is optimal.

The optimization result shows that there is some cost difference between the existing working system and the optimized one.

Optimized result cost= Existing cost -Optimization cost

= 2,932980 birr/month-2,926,000 birr/month

= 6980 birr/month

5.2.2 Distribution system

working hrs.	time	number of vehicles	capacity	frequency	amount unload/day
morning	2:30-6:30am	car 1	50 quintals	4	200
after noon	7:30-11:30am	car 2	30quintals	4	120
evening	12:30-2:00pm	car 3	50 quintals	5	234

Table 5.6: distribution time and vehicle capacity

Operation costs

driver	3000birr/month*3		9000birr/month
fuel cost	car 1	288birr*26days	7488birr/month
	car 2	492birr*26days	12792birr/month
	car 3	657birr*26days	17082birr/month
supporter	1400birr/month*3		4200birr/month

labor cost			
5birr/quintal*200	car 1	1000birr*26days	26000birr/month
5birr/quintal*120	car 2	600birr*26days	15600birr/month
5birr/quintal*234	car 3	1170birr*26days	30420birr/month

drivers commission			
1.5birr/quintal*200	car 1	300birr*26days	7800birr/month
1.5birr/quintal*120	car 2	180birr*26days	4680birr/moth
1.5birr/quintal*234	car 3	1351birr*26days	9126birr/month

Total= 144,188birr/month

Table 5.7: operational costs

Additional information's

working hr.	daily production capacity (existing system)	cost of product/quintal	Average daily demand
8hrs/day	800quintals/day	1950birr/quintal	554
26days/month	20,800quintals/month		

Table 5.8 production

Distribution system of the company

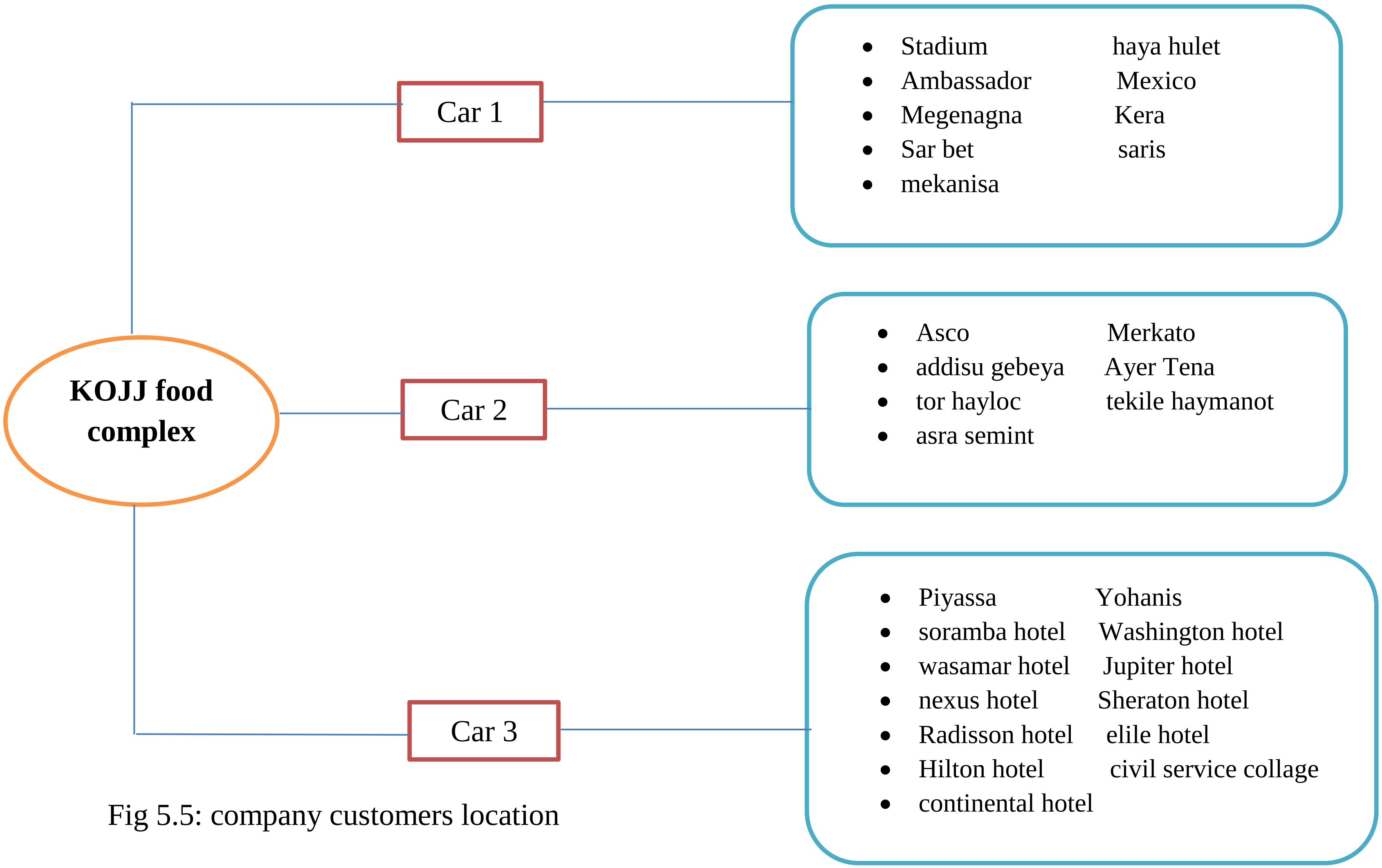


Fig 5.5: company customers location

Distribution routes of the company

Fig 5.6: distribution routine

Product distribution Model

The participants used in modeling and simulating the systems are: marketing, transport department, and production supervisors are participated in the data collection and discussion. And the routine recorded according to the existing schedule of each trucks destination. data collection is done in different working days (consecutive 5 days) and stop watch is used in measuring the processing time. The distribution system of the company determined by the number of trucks, the number of customers, demand and distribution location. The report of simulation run of replication length 1000 hrs. The utilization of resources (trucks and labors) shows the rate at which the resources be busy during the simulation time. trucks utilization is about 53.8 and the utilization of labors is about 58.4 busy in the stated simulation run length. The other results are depicted in annex 3 Generally, the report shows that the resource utilization of trucks as well as labor forces are very low. Since the distribution routines are unstudied and not logical, the other problem is when the loaded product they have to return and load the product even if there is a little amount the customer need since the company located at the out border of Addis Ababa city the company spent much cost to deliver its product. The truck returns to the company to load another product is 4.33times in average. This shows that company has to locate distribution centers to decrease the cost for product distribution.

Model assumptions

Set-up times are not taken into consideration, because in a real system the setup process is usually established at the end of the working time, 480 minutes working time does not include breaks.

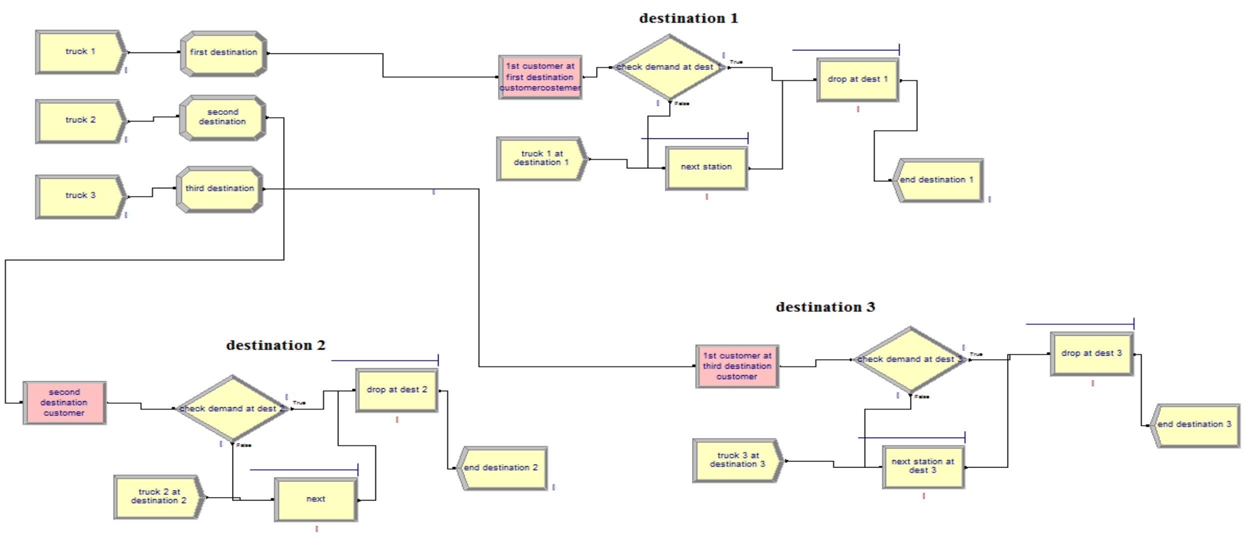
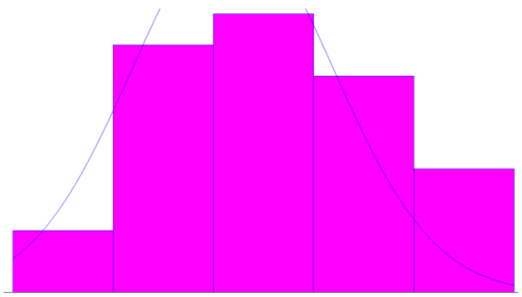


Fig 5.7 Distribution performance of the company on arena model

Analysis

Data collection is done for estimating model input parameters. The frequency back to the company, the unload processing time, time take to visit each customer, customer demand, and the required resources are collected during distribution process. The inputs of the collected data are analyzed with input analyzer of Arena to determine the distribution of these parameters. The fitness of these data is determined by taking the smallest squared error of the distributions.

Return to the company

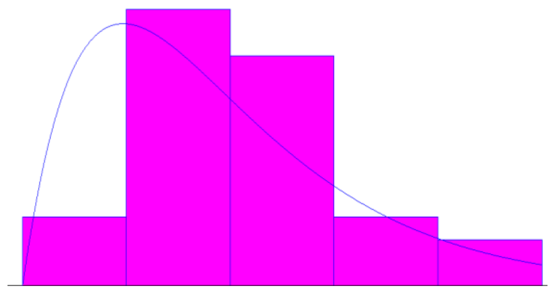


Distribution: Normal

Expression: NORM (4.13, 1.2)

Square Error:0.004691

time between customers

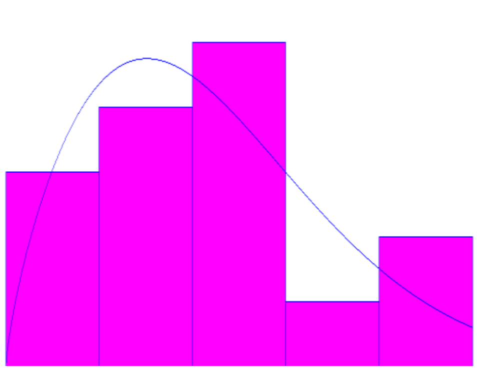


Distribution: Erlang

Expression:8.5 + ERLA (7.17, 2)

Square Error:0.045391

Customers Demand

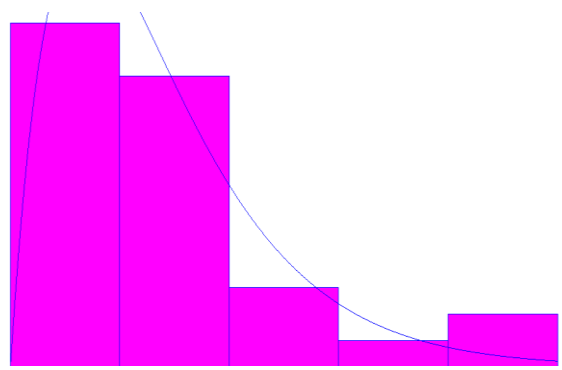


Distribution: Weibull

Expression: 6.5 + WEIB (14.4, 1.73)

Square Error: 0.021168

un load processing time



Distribution: Erlang

Expression: 8.5 + ERLA (3, 2)

Square Error: 0.008867

Fig5.8: distribution summaries of the simulation model

Model Verification

During the model translation, it is ensured that the simulation model has all the necessary components and that the model actually runs and checked the model operates as needed. The verification process on the simulation model is done by Test with various variations of input parameter values and step-by-step execution techniques. formulation of input parameters was checked to build the model correctly.

Model validation

The simulation trial runs under a variety of settings of the input parameters and checked the model output results for its correctness. And the results of the simulation model were discussed with the production managers, production supervisors, marketing, and transport department who are experienced in product distribution.

Locating the Distribution centers (factor rating method)

Performance characteristics of Distributor storage with package carrier delivery

The company now uses package delivery system but the transportation cost to frequently back to the company is higher and according to customers survey results availability of the product is lower, therefore: rather than the other distribution methods distributer storage with package delivery has the advantages of Lower Transportation than manufacturer storage, is highest for faster-moving items, Facilities and handling Somewhat higher than manufacturer storage, Items Simpler infrastructure compared to manufacturer storage Information Response time Faster than manufacturer storage Product availability Customer experience Better than manufacturer storage with drop-shipping.

For locating the distribution centers, the following criterions used to select the general territory of the locations:

1. **Cost of construction-** may vary from one territory to the other.
2. **Market may be concentrated or distributed** Locating a plant or facility nearer to the market is preferred if characteristics of service is required particularly if the product is susceptible to spoilage. In addition, if the product is relatively inexpensive and transportation costs add meaningfully to the cost, a location close to the market is desirable.

3. **Transport-** Refers to the external transportation of the raw material and the finished product. Adequate transportation facilities are essential for the economic operation of production system.

4. **Energy-** Other than electric power, in most plants it may be necessary to use gas, coal fuel oil.

5. **Infrastructure-** This factor refers to the availability and reliability of power, water, fuel and communication facilities in addition to transportation facilities.

Generally, the above selecting criterions (location factors) summarized as follows:

1. **Land availability and building costs-** lease land costs
2. **Nearness to the company -**distance from the milling company
3. **Proximity to market-** distance from customers
4. **Transportation –** transportation costs**,** availability of fuel stations
5. **Hotel and restaurants-**main consumers of wheat
6. **Financial and communication facilities: Banking** and financial institutions/services **(**Commercial Bank of Ethiopia, other financial institutions), communication (telephone), internet connection, road, water…etc.
7. **Labor availability and cost-**loading/unloading costs
8. **Population density –**number of population per square kilometer
9. **Future Expansion-**Availability of land for future expansion

To select the distribution centers; Land availability & building costs, Nearness to the company, Proximity to market, Transportation, Availability of Infrastructural facilities, Labor availability & cost, Population density are considered. To compute and select the distribution centers standard preference table is used.

Preference Level	**Numerical value**
Less preferred	1
Moderately preferred	2
Strongly preferred	3
Very strongly preferred	4
Extremely preferred	5

Table 5.9: standard preference table

According the survey, the products of the company is not much available easily in Addis Ababa as the other products but the company mostly hold inventory of finished goods until customers order a certain amount of product. Therefore, by locating some distribution centers in selected sub cities of Addis Ababa the company can manage its distribution problems as well as minimize holding cost of inventories.

To decide the distribution centers of products the research uses factor rating method, the technique develop some factors that affect the distribution system with related to the company location and giving weights for each factor decide the distribution facility by taking the highest total weight location.

Directions	**Land availability and building costs**	**Nearness to the company**	**Transportation(Cost/km) =1.74 birr**	**Hotels and restaurants (Renown Hotels)**	**Population density** (per sq. m)	**Labor availability and cost**	**Financial and communication facilities:**
Addis ketema sub city	211 birr/m2	5.5km	9.57	3	36,659.1	40 birrs	✓
Kolfe keranio sub city	211 birr/m2	Company location	-	7	7,448.5	40 birrs	✓
Nifassilk lafto sub city	211 birr/m2	14.8km	25.752	3	4,915.7	40 birrs	✓
Lideta sub city	211 birr/m2	8.6km	14.964	10	23395.3	40 birrs	✓
Akaki Kaliti sub city	211 birr/m2	19.5km	13.72	3	1,653.7	40 birrs	✓
Bole sub city	211 birr/m2	9.8km	17.052	7	2,694.1	40 birrs	✓
Yeka sub city	211 birr/m2	7.7km	10.78	10	4,284.9	40 birrs	✓
Arada sub city	211 birr/m2	4.6km	6.44	5	22,805.1	40 birrs	✓
Gulele sub city	211 birr/m2	9.7 km	16.874	2	9,438.9	40 birrs	✓
Kirkos sub city	211birr/m2	8.1km	11.34	5	16,104	40 birrs	✓

Table 5.10: general data for selection

Source: Addis Ababa city administration website

Directions	Land availability and building costs	Nearness to the company	Proximity to market	Transportation	Hotels and restaurants	Financial and communication facilities:	Labor availability and cost	Population density	Total
Addis ketema sub city	5	4	5	4	3	5	5	5	36
Kolfe keranio sub city	5	4	4	4	5	5	5	3	35
Nifassilk lafto sub city	5	3	2	3	4	5	5	5	32
Lideta sub city	5	4	3	4	4	5	5	3	33
Akaki Kaliti sub city	5	3	2	3	3	4	5	2	27
Bole sub city	5	4	4	4	5	5	5	5	37
Yeka sub city	5	4	3	4	4	5	5	5	35
Arada sub city	5	5	5	5	4	5	5	3	37
Gulele sub city	5	5	5	5	3	5	5	3	35
Kirkos sub city	5	4	4	4	5	5	5	5	37

Table 5.11: factor rating weights

Because of the resources to deliver products we locate maximum of four locations Therefore, the highest weight sub cities selected Addis ketema sub city, Kirkos sub city, bole sub city, Arada sub city the company locate and already has a distribution center at kolfe keranio sub city should ignored. By locating additional four distribution centers, the company can change its market from produce store to produce sell system. In basic science terms from push to pull system

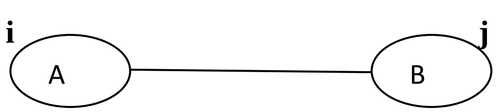
These distribution centers will facilitate the distribution of wheat products. They will distribute their products to each customer by getting the products from the manufacturers. They are intimidator between the manufacturer and the customer. Hence, these distribution centers help increases customer satisfaction.

Distribution centers optimization

Distribution centers	**Land availability and building costs**	**Nearness to the company**	**Transportation(Cost/km) =1.74 birr**	**Labor availability and cost**	**Time**
Addis ketema sub city	211 birr/m2	5.5km	9.57	40 birrs	16 min
Kirkos sub city	211 birr/m2	9.7 km	16.874	40 birrs	21min
Arada sub city	211 birr/m2	4.6km	6.44	40 birrs	13min
Kolfe keranio sub city	211 birr/m2	Company location		40 birrs	
Bole sub city	211 birr/m2	9.8km	17.052	40 birrs	27min

Table 5.12: selected distribution centers

Let the direction from A to B and the cost of transportation cost from I to j (Cij) for many directions (Xij),



$$\textbf{Min} = \sum_{i} \sum_{j} C_j X_{ij}$$

Minimum spanning tree method

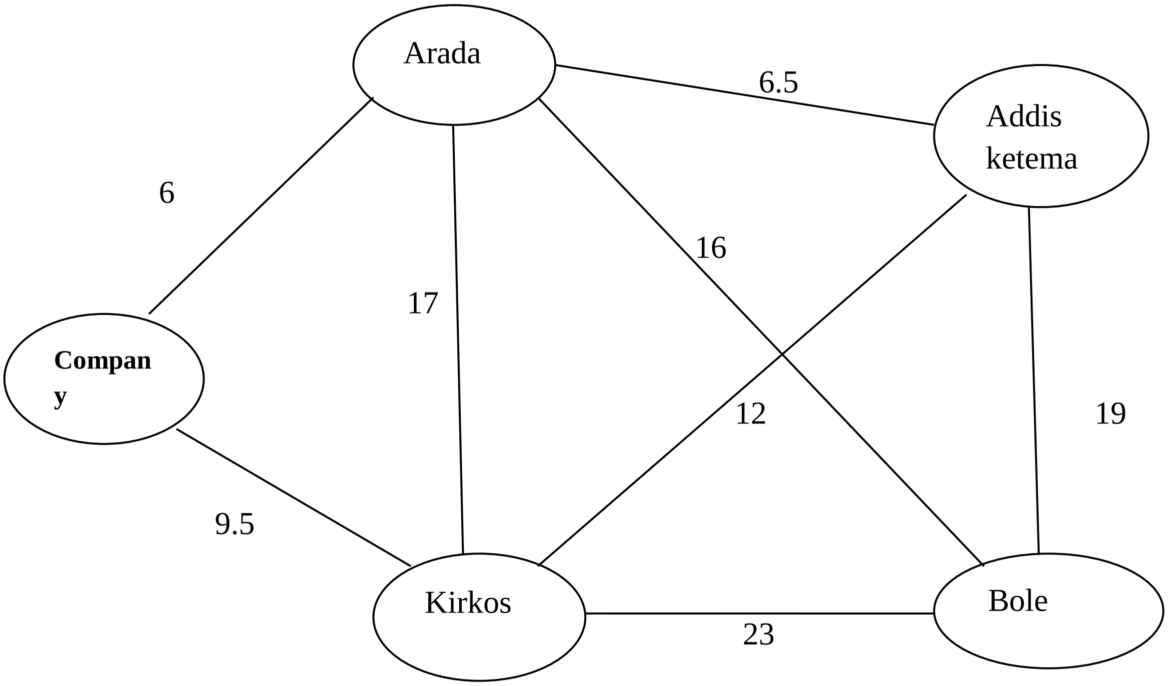
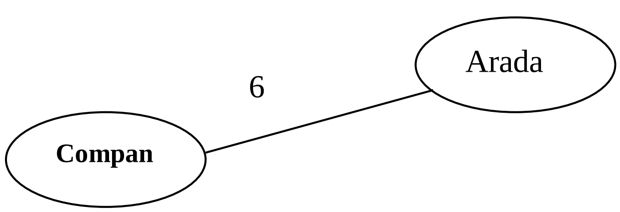


Fig 5.9: spanning tree

This is the transportation routine to deliver products from the company to selected distribution centers, the question here is which one of the routine the cost effective as well as when the cost optimizes at the same time the distance and time will be optimized. There are different kinds of transportation optimization techniques one of them is minimum spanning tree method Under minimum spanning tree there are two types of algorithms,

1. **Prims algorithm**
2. **Kruskal algorithm**

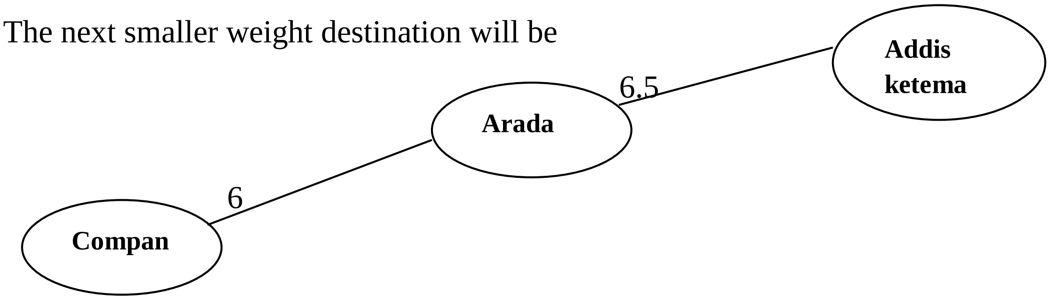
Prims algorithm is the network minimization algorithm based on minimum weight of the destination. Let take the minimum destination from the network



S1= [company, Arada]

S2= [Kirkos, Addis ketema, bole]

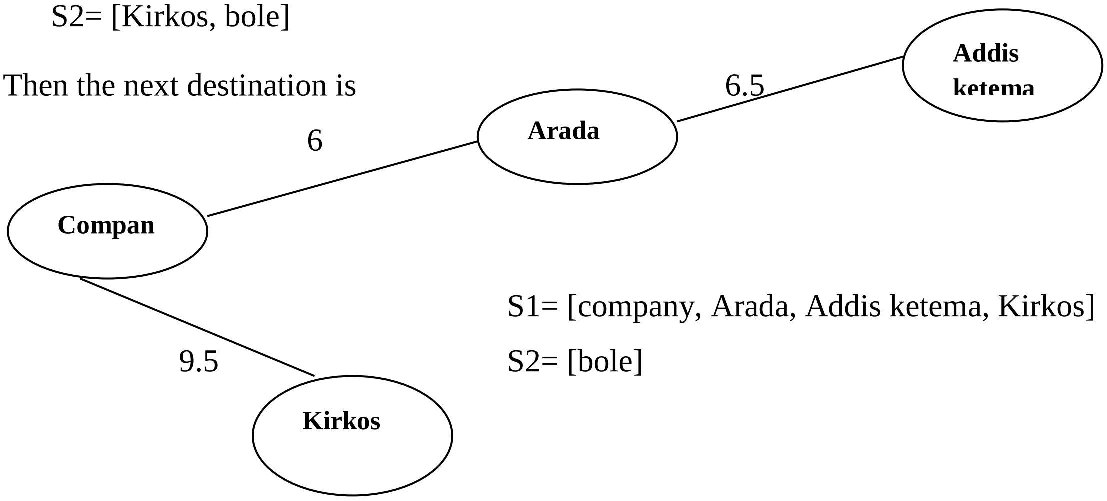
The next smaller weight destination will be



S1= [company, Arada, Addis ketema]

S2= [Kirkos, bole]

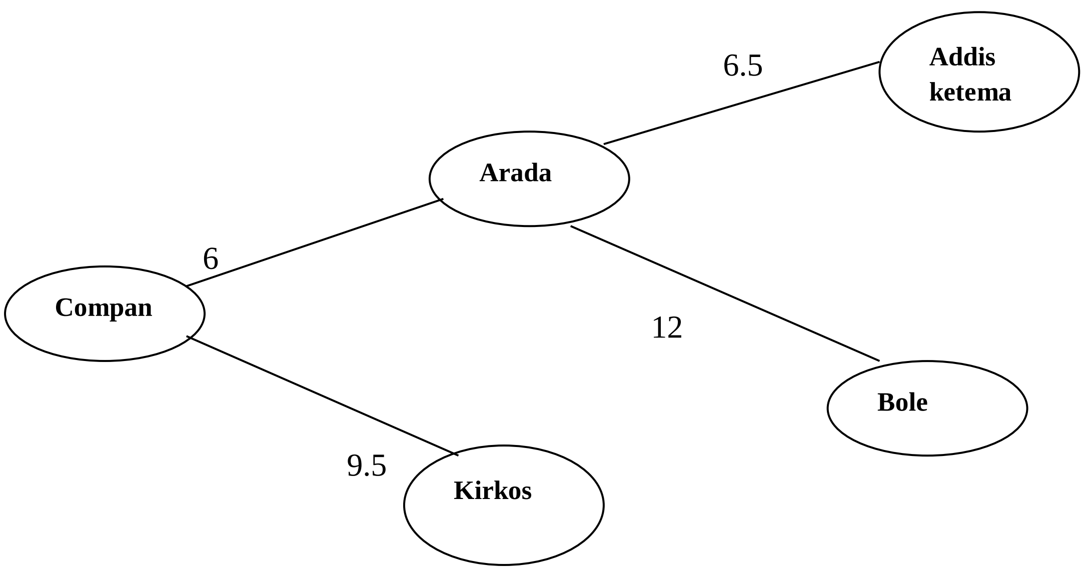
Then the next destination is



S1= [company, Arada, Addis ketema, Kirkos]

S2= [bole]

We going to optimize until the whole destinations filled; the final destination will be bole sub city



- Therefore, the optimized distribution network is [Company, Arada sub city, Addis ketema sub city, Kirkos sub city, and bole sub city] with the total transportation cost of 34birr.

2. Kruskal algorithm: is a minimum span tree algorithm based on arranging the destinations by their increasing order and connect the network following the weight. However, the network must be a tree. From our case:

1-2=6

2-4=4

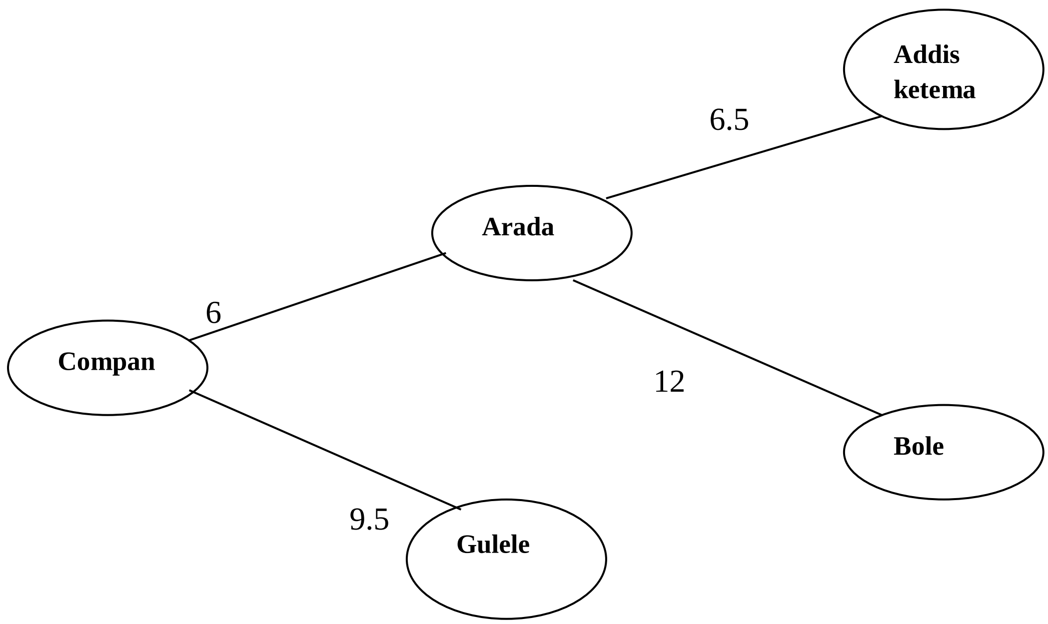
1-3=9.5

3-4=12

2-5=16

2-3=17

4-5=19



- Therefore, the optimized distribution network is [Company, Arada sub city, Addis ketema sub city, Gulele sub city, and bole sub city] with the total transportation cost of 34birr.
- Both techniques give us the same result, and this transportation network is the optimal solution by minimum span tree technique.

Distribution facility cost

Distribution centers	Land/building rent	Cost	Employee	Cost	Storage capacity
Addis ketema sub city	**Storage** 8m2*8m2 **Office** 2m2*2m2	4000birr+1200birr	Gurds (2) Casher (1) Manager (1) Labor (3)	2000*2=4000birr 1300birr 4000birr 80*3=120birr/day= 26*120=6240birr/ month	28quintals/m2*8m2 = 224 quintals

Table 5.13 distribution facility cost

Source: own survey data

Total cost for a single distribution center 20,740 birr/month by taking Addis ketema sub city as bench mark because the area is more business center than the others. Therefore, for the others by assuming the cost is not greater than Addis ketema sub city the total cost for distribution cost is 82960birr/month

Saved cost =Cost spent for distribution – cost spent for locating distribution cost

=144,188birr/month - 82,960birr/month

= 61228 birr/month

Distribution centers on Addis Ababa map

Company location

Distribution centers

Fig 5.10: distribution centers location on Addis Ababa city map

5.2.3 Inventory management model

This paper is done using Rockwell simulation software ARENA to simulate the inventory management as well as production process of the company. The methods used in modeling and simulating the systems are:20 operators, quality department supervisors, and production supervisors are participated in the data collection and discussion. data collection is done in different working days (consecutive 5 days) and stop watch is used in measuring the processing time. Data are collected on demand of customers, milling machine, and washing machine, drying machine, and packaging processing times per quintal.

The inventory management of the company is determined by the level of inventory, demand, order placed. The report of simulation run of replication length 1000 hrs. shows that the raw material requirement 33,263 quintals to produce 32,027 quintals flour. The determination of the quantity of order and the beginning raw material inventory can be done with trial and error using process analyzer.

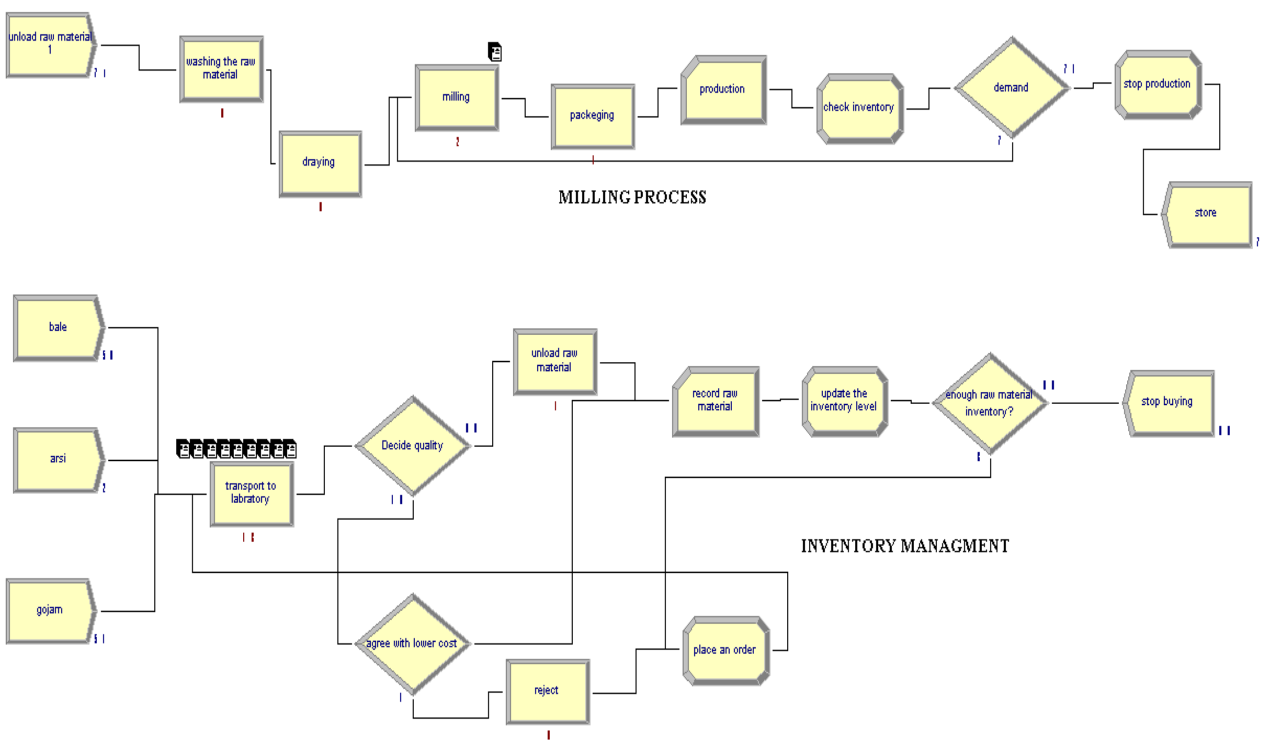


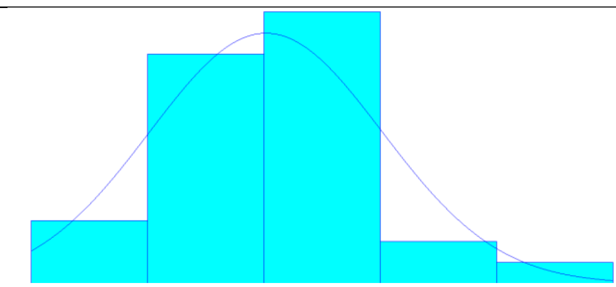
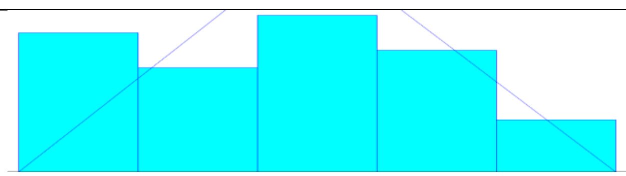
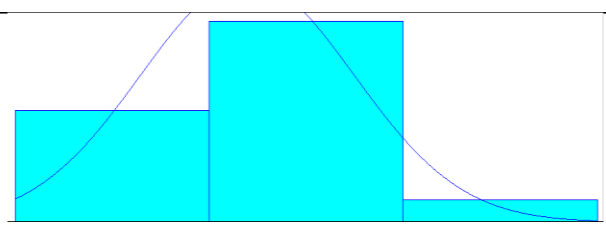
Fig 5.11: Inventory management and milling process model

Milling Process Model

The utilization of resources (machines and operators) shows the rate at which the resources be busy during the simulation time. milling machine utilization is about 51. % busy in the afore mentioned simulation run length. The operators in packaging process operate with 59 %. The other results are depicted in Appendix   Generally, the report shows that the resource utilization of machines as well as operators are very low. Since electric city interruption, slow raw material feeding and there is no proper preventive maintenance schedule, the failure of machines influences the process utilization and efficiency.

Data Analysis

Data collection is done for estimating model input parameters. The sequence of processes, the processing time, and customer demand, the failure rate of machines, the reorder level, safety stock and the required resources are collected during milling process. The inputs of the collected data are analyzed with input analyzer of Arena to determine the distribution of these parameters. The fitness of these data is determined by taking the smallest squared error of the distributions.

Operation	Graphical representation
Raw material arrival Distribution Summary Distribution: Normal Expression: NORM (796, 236) Square Error: 0.015073	
Washing machine Distribution Summary Distribution: Triangular Expression: TRIA (3.5, 31, 59.5) Square Error: 0.037248	
Drying machine Distribution Summary Distribution: Normal Expression: NORM (24.4, 9.19) Square Error: 0.002146	

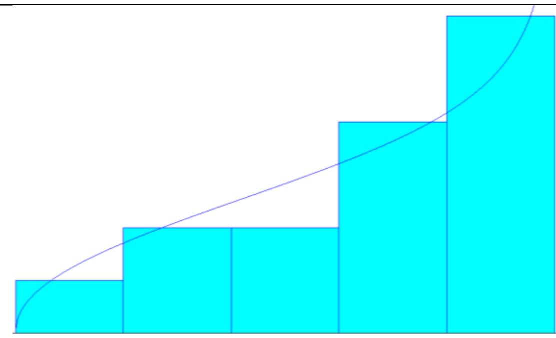
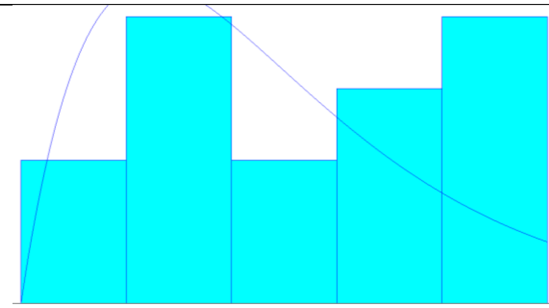
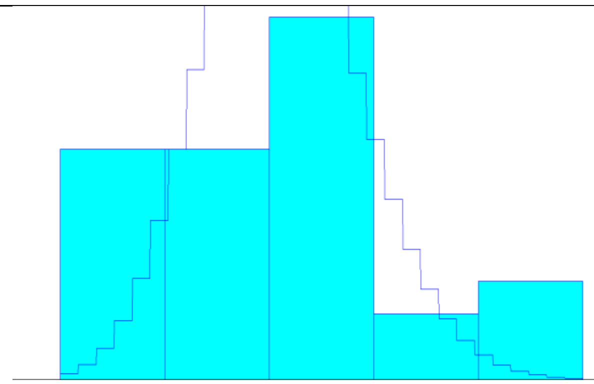
Packaging machine Distribution: Beta Expression: 8.5 + 15 * BETA (1.45, 0.81) Square Error: 0.004604	
Milling machine Distribution Summary Distribution: Erlang Expression: 8.5 + ERLA (4.2, 2) Square Error: 0.027792	
Demand Distribution Summary Distribution: Poisson Expression: POIS (18.8) Square Error: 0.165710	

Table 5.14: Distribution fitness data and graph

Model Verification

During the model translation, it is guaranteed that the simulation model has all the necessary components and that the model actually runs and checked the model operates as intended. The verification process on the simulation model is done by Test with various combinations of input parameter values and step-by-step execution techniques. Moreover, formulation of input parameters was checked to build the model correctly.

Model assumptions

Set-up times are not taken into consideration, because in a real system the setup process is usually accomplished at the end of the working time, 450 minutes working time does not include breaks, there is no maintenance process performed during the working period.

Throughput Verification.

The verification of the model can be done considering the estimated throughput, $\delta(r)1=D(r)/T(r)$, where $\delta(r)1$ is throughput estimator for a given replication r D(r) is the number of jobs processed to completion during replication r, and T(r)is the duration of replication r. (Eshetie Berhan, October 2014)

$\delta(r)_1$=14,400/1000

=14.4

The above calculated throughput estimators are close to the initial value of arrival rate i.e. 14.43 jobs per hour. Consequently, these verification facts support the contention that the model is correct.

Model Validation

Validation assesses how realistic the modeling assumptions are, by comparing model performance metrics (predictions), obtained from model test runs, to their counterparts in the system under study. Simulation trials were done using process analyzer and the closeness to the real data collected was checked to validate the model whether it was a correct built model. Validation activities are critical to the construction of credible models. The standard approach to model validation is to collect data (parameter values, performance metrics, etc.) (Eshetie Berhan, October 2014)

The results of the simulation model were discussed with the production managers and production supervisors who are experienced in this milling process. The newly developed model and operation is verified with users/operators of the actual system. The model input of raw materials with the output of the model is compared and it shows a good closeness.

5.3 Supply chain network Design

Network development may involve issues relating to plant, warehouse, transportation, and retailer location. These are strategic decisions have a long-lasting effect on the company. To come up with a better network design, appropriate numbers of warehouses, location of each Warehouse, and the size and capacity of each warehouse have to identified and determined. The objective of supply chain network design in this case is to use the available resources efficiently and effectively, minimize the total costs, improve customer satisfaction; then to improve market share. Increasing the number of distribution centers typically yields: improvement in service level, increase in inventory costs, increase in overhead and set-up costs, reduction in outbound transportation costs, and increase in inbound transportation costs. This means opening distribution centers at all the proposed locations. Thus, distribution location decisions are critical determinants for the efficiency of the product distribution. A general Mathematical Model (MM) of the supply chain network design presented in. The total cost function is the minimum value of sum of company costs, transportation cost in supply of raw material and distribution of finished goods. The objective is to design the SC network so as to minimize annual system-wide costs and improve service level requirements, thereafter increase market share. Increasing the number of warehouses typically yields: improvement in service level, increase in inventory costs, increase in overhead and set-up costs, reduction in outbound transportation costs, and increase in inbound transportation costs. In this setting, the tradeoffs are clear. In essence, the firm must balance the costs of opening new warehouses with the advantages of being close to the customer. Thus, warehouse location decisions are crucial determinants for the efficiency of the product distribution. The design approaches therefore, require the following three major activities to produce a good optimized result. (Chopra, 2006) and (Daniel Kitaw, 2011)

1. Data collection and aggregation regarding transportation rates, warehouse costs, and service level requirements.
2. Modeling.
3. Use of solution techniques.

Objective function

$$min = \sum_{i=1}^{n} FiYi \sum_{e=1}^{t} tefe + \sum_{h=1}^{s} \sum_{i=1}^{n} CbiXbi + \sum_{i=1}^{n} \sum_{e=1}^{t} QieXie$$

Subject to

The total amount shipped from a supplier can’t exceeds the supplier's capacity;

$$\sum_{i=1}^{l} Xbi \leq Sb \; for \; b = 1,2,3 \dots s$$

Amount shipped out of factory cannot exceed the quantity of raw material received;

$$\sum_{i=1}^{l} Xbi - \sum_{e=1}^{t} Xie \geq 0 for \; i = 1,2,3..n$$

Units produced in factory cannot exceed factory capacity

$$\sum_{e=1}^{t} Xie \leq KiYi \; for \; i = 1,2,3 \dots n$$

Amount shipped through warehouses cannot exceed its capacity;

$$\sum_{j=1}^{m} Xej \leq WeYe \; for \; e = 1,2,3 \dots t$$

$\boldsymbol{YiYe\{0,1\}, Xie, Xbi \geq 0}$

n= number of potential factory locations

s= number of suppliers

t= number of potential warehouse locations

Ki= potential capacity of factory at site i

Sh= supply capacity at supplier h

Cbi = cost of shipping one unit from supply source h to factory i

We= Potential warehouse capacity at site e

Decision variables:

Y_i= 1 if warehouse is located at site i, 0 otherwise

Y_e= 1 if warehouse is located at site e, 0 otherwise

X_{bi}= quantity shipped from supplier h to factory at site i.

X_{ie}= quantity shipped from factory at site i to warehouse e

5.3.1 new supply chain network

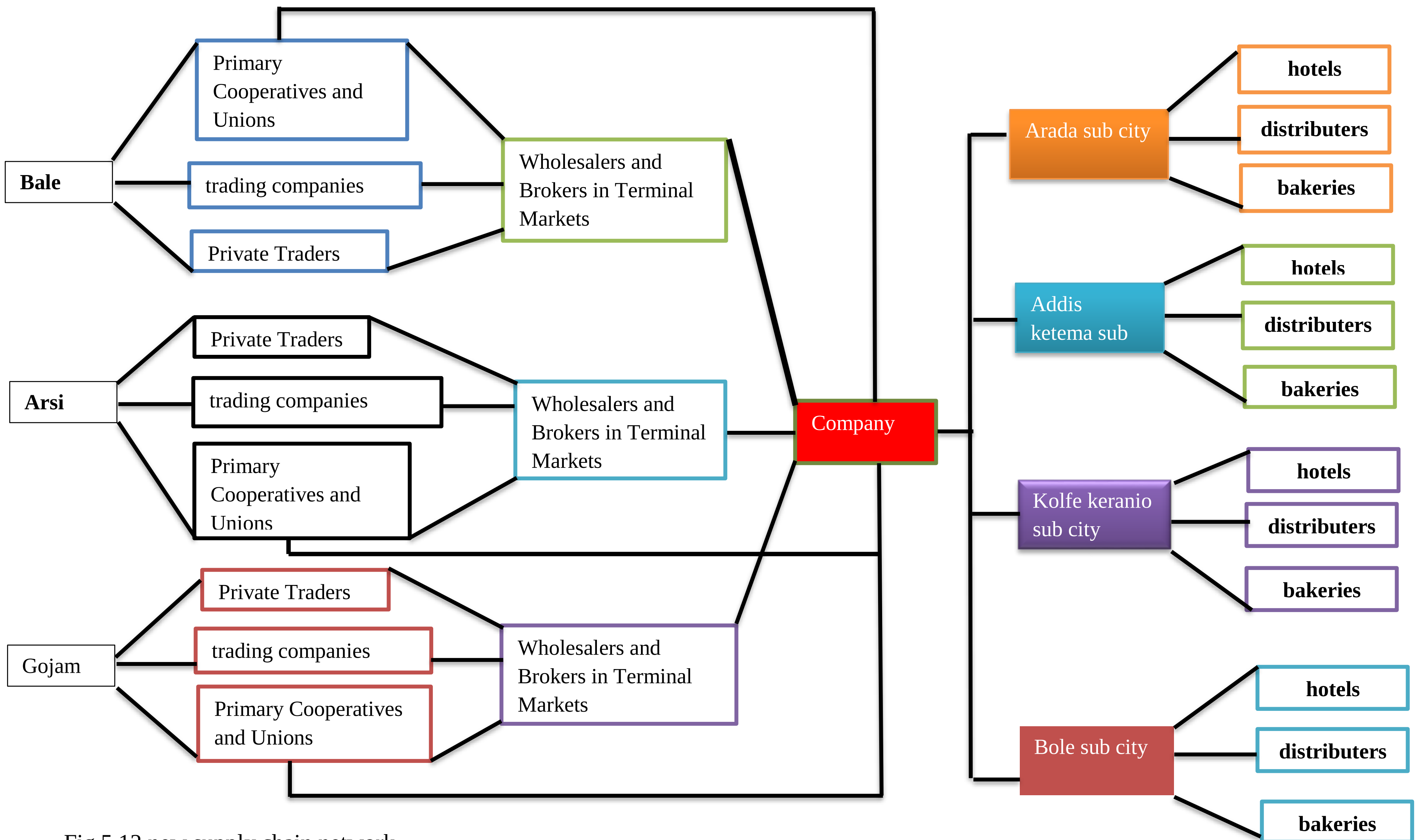


Fig 5.12 new supply chain network

CHAPTER SIX: CONCLUSION, RECOMMENDATION AND FUTURE WORK DIRECTION

6.1. CONCLUSION

In this paper the researcher tries to identify the problems related with supply chain network then review different literatures, scenarios and methods to solve the problems by using different optimization tools and validate with arena simulation software. The result indicates that cooperatives and unions as actor and companies should work together to increase the quality and price regulation areas because of the intervention of illegal bodies the sector highly challenged in addition to this using certified and modern cultivation, transportation and storage wheat productivity can have increased. Working financial capital and network with wheat processing industries were found to be constraints for trader's wheat supply for wheat processors. Moreover, the quantitative result of the paper shows that by optimizing transportation cost of raw material supply it can save 83,760birrs annually. Executing supplier relationship system, it can increase the quality of raw material and saves 478,800birr annually, the company distributes its products with high distribution cost but according to this research result locating distribution centers can save from the existing expense by 734,736birr/year and improves delivery performance. finally, inventory model result indicates that low preventive maintenance and labor utilization is the critical causes for decreasing the amount the company produce.

6.2 RECOMMENDATION

The researcher has made some recommendations based on the study that has been conducted. First of all, the researcher would like to recommended that on raw material supply decision. because of lack of strong and legal relationship with the suppliers it spent much money on mixed impurities, the company can use suggested framework in this study as it can help developing trusted supplier relationship and the other point related to raw material supply the company is better to follow cost effective areas with demanded quantity.

Moreover, the company needs to work on its inventory management system. in the study the utilization of resources, preventive maintenance, alternative electric source and producing by considering the demand of the customer are the areas which the company think to increase the production capacity.

Finally, the distribution system of the company is highly costly system and focused on the trusted customers but the lower consumers complained on the availability of the product in the other side the company holds inventories of finished goods to make this balance locating distribution centers near to the customers is critical issue to minimize holding cost and increase market share.

Generally, the researcher would like to suggest that studying every point of the supply chain is a continuous task to study in detail a better culture of documentation, especially in the area of the important process parameters is needed. the companies which are known in the world spend much money on research and development area because of it can improve the whole firm profitability and customer satisfaction.

6.3 FUTURE RESEARCH DIRECTION

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

- In this study the researcher tries to collect data related to vehicles routine and proposed the existing distribution routines but it isn't optimized, there are different methods and techniques to optimize vehicle routine problems. Therefore, the future research areas can address this problem.

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APPENDIX

QUESIONERS FOR FARMERS

I. Dear Respondent,

Addis Ababa university master's thesis entitled **"SUPPLY CHAIN NETWORK DESIGN AND ANALYSIS USING SIMULATION ANALYSIS"** with the objective to carry out an in-depth supply chain analysis to generate sufficient information on the main opportunities and bottlenecks for wheat products. this study is likely to contribute significantly to increase supplier. Production, distribution performance. Put (X) to each answer where you feel appropriate. Your response will only be used for survey purposes and never be shared. In case you have any questions regarding the survey, please call tewodros tolosa 0910672073**Thank you very much for your time and suggestions.**

General Information:

Farmer's Name: ______________________________ Sex: _________

Zone: ________________Woreda: _____________ Farm size/ha: _________

1. What type of seed do you use to plant your farm/plot?

a. Certified seeds, from seed enterprises______________

b. Commercial seeds, from unions___________________

c. Local seeds, from your own source-----------------

d. Others type, specify-----------------------------------

2. Who is your produce's major buyer?

a. Private small buyers_________________

b. Big whole sale buyers/traders___________

c. Flour factories_________________________

d. Government Organizations______________

c. Others specify_____________

3. The selling price of your wheat produce for 100kgFor the following production season

2015	2016	2017	2018

4. How do you characterize the price of wheat

a. Highly fluctuating____________

b. Fluctuating_________________

c. Predictable_________________

d. Others, specify_______________

5. What type of storage do you have for your wheat produce?

a. Traditional storage __________________-

b. Well prepared ware house________________

c. Others, specify________________________

6. Are you aware of the industrial wheat quality requirement

a. yes, and I am working to meet those requirement

b. no

c. other, specify_________________________

7. what are your limitations to produce according to milling factories requirements?____

____

Thank you for sharing your thoughts with us!!!

QUESIONERS FOR PROCESSOES/FACTORY

II. Dear Respondent,

Addis Ababa university industrial engineering master's thesis entitled **"SUPPLY CHAIN NETWORK DESIGN AND ANALYSIS USING SIMULATION ANALYSIS"** with the objective to carry out an in-depth supply chain analysis to generate sufficient information on the main opportunities and bottlenecks for wheat products. this study is likely to contribute significantly to increase supplier. Production, distribution performance. Put **(X)** to each answer where you feel appropriate. Your response will only be used for survey purposes and never be shared. In case you have any questions regarding the survey, please call tewodros tolosa 0910672073**Thank you very much for your time and suggestions.**

III. General Information

a) Name of the factory: ____

b) Location of the Factory: ____

c) Contact Person: ____

d) Address, Tel Number: _________________________ E. mail: __________________

e) Year of establishment or start of operation (Ethiopian calendar): ____________________

1. What is the major wheat product produced at your factory?

a. Flour _________

b. Pasta _________

c. Macaroni _________

d. Biscuit _________

e. Other, Specify _______

2. What is the amount of your factory processing capacity?

a. On Daily basis ___________

b. Annually_________

3. How is the quality of your product determined

a. By the quality of the raw material _____________________

b. By the factory /plant type____________________

c. By employee's unique knowledge________________

d. By good company leadership___________

4. Does your factory location and its facilities suitable for a higher output?

a. It is not suitable___________________________

b. We need to move in to a new and suitable factory site________________

c. It is suitable for our production activity__________________

d. We are doing under difficult conditions________________

5. Do you have any plan or strategy to create long term wheat suppliers/farmers partnership?

a. We have already formed a good relationship____________________

b. We are planning to form a relationship ____________________________

c. It is not part of our strategy for the time being_____________________

d. There is no need to form long term partnership___________________

6. Your major source of wheat materials is from?

a. Individual farmers _____________

b. Unions ____________

c. Ethiopian Grain Trade Enterprise (EGTE) ________

d. Private wholesale traders ___________

e. Private small traders____________

f. Agents or broker___________

7. How do you describe your factory's processing and manufacturing capabilities?

a. Our factory plant is a bit old needs replacement ________________

b. We have an old factory but working good still___________________

c. We have a modern and up-to-date plant factory____________________

d. The business does not need a very up-to-date factory plant_________

6. How is the quality of your product determined

a. By the quality of the raw material ____________________

b. By the factory /plant type___________________

c. By employee's unique knowledge_______________

d. By good company leadership___________

7. What are the major reasons of decreasing your production capacity from the previous seasons.____
____.

8. What are the distribution strategies of your products?____
____.

9. how did you see the intervention of brokers?____
____.

10. The major limitations to work with farmers and farmers unions?____
____
____.

11. What do you think is the constraint for an effective wheat flour supply chain in our country?

____

____

____.

12. Your suggestions the way improve the supply chain for the wheat flour industry?____

____

____.

Thank you for sharing your thoughts with us!!

የካ.ኦ.ጂ.ጂ ዱቄት ተጠቃሚዎች መጠይቅ

አዲስ አበባ ዩኒቨርሲቲ ቴክኖሎጂ ኢኒስቲትዩት መካኒካል እና ኢንዱስትሪል ኢንጂነሪንግ ትምህርት ክፍል፡፡

ውድ መልስ ሰጪዎች ይህ መጠይቅ የተዘጋጀው ለሁለተኛ ዲግሪ መመረቂያ ፅሁፍ መረጃ ለመሰብሰብ የሚያግዝ ሲሆን ሌላ ምንም ዓይነት አላማ እንደሌለው እናረጋግጣለን፡፡ ለሚስጡን መረጃ ከልብ እያመሰገንን በጥያቄዎቹ ላይ ግልፅ ያልሆኑ ነገሮች ካሉ **ቴዎድሮስ ቶሎሳ** **<u>09 10 67 20 73</u>** መደወል ይችላሉ፡፡

1. የካኦጂጂጂ ዱቄትን ተጠቅመው ያውቃሉ
   ሀ. በዐመት አንድ ግዜ
   ለ. በየቀኑ
   ሐ. በየሳምንቱ
   መ. በየወሩ
   ሠ. ተጠቅሜ አላውቅም

2. በአቅርቦታቸው ደስተኛ ነኝ (ገበያ ላይ በቀላሉ ይገኛል)
   ሀ. እስማማለው
   ለ. አልስማማም
3. ለምን?--

   ---፡፡
4. በምርቱ ላይ ችግር አጋጥሞት ያውቃል
   ሀ. አዎ ጋጥሞኛል
   ለ. አጋጥሞኝ አያውቅም
5. ካጋጠሞት ቅሬታውን ለማን አቀረቡ
   ሀ. ለገዛውበት ሱቅ
   ለ. ለፋብሪካው

6. በእርሶ ግንዛቤ የካኦጂጂ ዱቄት **በጥራት** ከሌሎች የዱቄት ጋረ ሲነፃፀር
   ሀ. የተሻለ ነው
   ለ.ያነሰ ነው
   ሐ. ተመሳሳይ ነው

7. በእርሶ ግንዛቤ የካአጄጄ ዱቄት **በዋጋ** ከሌሎች የዱቄት ጋረ ሲነፃፀር

   ሀ. የተሻለ ነው

   ለ. ያነሰ ነው

   ሐ. ተመሳሳይ ነው

8. በ ካ.አ.ጄ.ጄ ምርት እና ስርጭት ዙሪያ መሻሻል አለበት ብለው የሚጠቁሙት ሀሳብ ካሎት እባኮትን በተዘጋጀው ባዶ ስፍራ ላይ ያስቀምጡልን--

ሀሳቦን ስላካፈሉን ከልብ እናመሰግናለን፡፡

Annex 1

Supply information into both companies for 16 months

Wheat to the company Supply from bale (from 1/3/2009 to 30/6/2010 ec)

Month	Supply/tone	Asco branch	Burayu branch
1	1400	732	668
2	1403	735	668
3	1409	740	669
4	1402	732	670
5	1403	735	668
6	1401	732	669
7	1401	733	668
8	1413	742	671
9	1406	732	674
10	1402	733	669
11	1405	736	669
12	1407	732	675
13	1409	741	668
14	1411	741	670
15	1404	732	672
16	1411	738	673

Wheat to the company Supply from Arsi (from 1/3/2009 to 30/6/2010 ec)

Month	Supply/tone	Asco branch	Burayu branch
1	1300	602	698
2	1319	621	698
3	1301	602	699

4	1302	602	670
5	1311	613	698
6	1304	616	698
7	1312	612	700
8	1302	602	700
9	1312	604	708
10	1310	605	705
11	1320	608	710
12	1303	603	700
13	1305	605	700
14	1302	604	698
15	1308	610	698
16	1302	602	700

Wheat to the company Supply from Gojam (from 1/3/2009 to 30/6/2010 ec)

Month	Supply/tone	Asco branch	Burayu branch
1	1100	1066	34
2	1101	1066	35
3	1100	1066	34
4	1105	1070	35
5	1106	1066	40
6	1102	1068	34
7	1135	1069	36
8	1108	1071	37
9	1105	1070	35
10	1102	1066	36
11	1106	1072	34
12	1100	1066	34
13	1108	1070	38
14	1104	1067	37
15	1101	1067	34
16	1103	1067	36

Source: from company's transport operation department

Annex 2

Distribution data

customer location	**amount un load**	**starting time**	**amount in birr**	**distance**
company	0	2:30am	0	0km
Asco	27quintals	9min	52650 birrs	1.2km
Piyassa	33quintals	20min	64350birr	4.6km
stadium	20quintals	21min	39000birr	11.1km
Merkato	35quintals	19min	68250birr	5.5km
addisu gebeya	21quintals	17min	40950birr	9.7km

Yohanis	20quintals	17min	39000birr	4.3km
haya hulet	18quintals	25min	35100birr	14.5km
soramba hotel	10quintals	21min	19500birr	4.6km
Washington hotel	9quintals	30min	17550birr	9.8km
ambassador	16quintals	27min	31200birr	16.1km
Mexico	17quintals	17min	33150birr	9.6km
Ayer Tena	25quintals	16min	48750birr	2.5km
wasamar hotel	7quintals	27min	13650birr	16km
Jupiter hotel	16quintals	25min	31200birr	8.1km
Megenagna	23quintals	30min	44850birr	16.7km
nexus hotel	7quintals	32min	13650birr	9.8km
Sheraton hotel	18quintals	20min	35100birr	5km
Radisson hotel	8quintals	24min	15600birr	8.1km
elile hotel	13quintals	23min	25350birr	8.3km
saris	22quintals	45min	42900birr	18km
Kera	20quintals	24min	39000birr	12.5km
Sar bet	21quintals	19min	40950birr	11.6km
Hilton hotel	15quintals	25min	29250birr	8km
tor hayloch	22quintals	10min	42900birr	2.8km
mekanisa	22quintals	29min	42900birr	14km
tekile haymanot	32quintals	19min	62400birr	5.5km
asra semint	23quintals	9min	44850birr	2km
civil service collage	22quintals	41min	42900birr	20km
continental hotel	12quintals	25min	23400birr	7.9km

Customer demand and location

Source: company marketing department

Annex 3: distribution model report

Replications:	1,000	Time Units:	Minutes

Key Performance Indicators

System	Average
Number Out	281

Replications: 1,000 Time Units: Minutes

Entity

Time

VA Time	Average	Half	Minimum Average	Maximum Average
wheat flour	49.7744	< 0.26	38.9244	66.8793

NVA Time	Average	Half	Minimum Average	Maximum Average
wheat flour	0.00	< 0.00	0.00	0.00

Wait Time	Average	Half	Minimum Average	Maximum Average
wheat flour	148.30	< 4.25	38.2887	453.01

Transfer Time	Average	Half	Minimum Average	Maximum Average
wheat flour	0.00	< 0.00	0.00	0.00

Other Time	Average	Half	Minimum Average	Maximum Average
wheat flour	0.00	< 0.00	0.00	0.00

Total Time	Average	Half	Minimum Average	Maximum Average
wheat flour	198.07	< 4.41	81.8712	511.86

Other

Number In	Average	Half	Minimum Average	Maximum Average
fuel	0.00	0.00	0.00	0.00
man power	0.00	0.00	0.00	0.00
wheat flour	282.05	0.96	233.00	341.00

Replications: 1,000 Time Units: Minutes

Entity

Other

Number Out	Average	Half	Minimum Average	Maximum Average
fuel	0.00	0.00	0.00	0.00
man power	0.00	0.00	0.00	0.00
wheat flour	280.69	0.95	233.00	341.00

WIP	Average	Half	Minimum Average	Maximum Average
fuel	0.00	< 0.00	0.00	0.00
man power	0.00	< 0.00	0.00	0.00
wheat flour	4.4693	< 0.10	1.7373	11.3021

Queue

Time

Waiting Time	Average	Half	Minimum Average	Maximum Average
drop at dest. 1. Queue	38.5590	< 1.00	11.6409	159.06
drop at dest. 2. Queue	38.5254	< 0.95	10.1515	121.12
drop at dest. 3. Queue	39.8501	< 1.04	12.7957	139.89
next station at dest. 3. Queue	606.13	< 25.19	32.8938	2017.61
next station. Queue	577.25	< 21.44	14.9123	2188.80
next. Queue	505.39	< 18.66	33.4816	1627.08

Other

Number Waiting	Average	Half	Minimum Average	Maximum Average
drop at dest 1. Queue	0.2893	< 0.01	0.07275544	1.4275
drop at dest 2. Queue	0.2833	< 0.01	0.07239453	1.0190
drop at dest 3. Queue	0.3141	< 0.01	0.08715044	1.0761
next station at dest 3. Queue	1.0321	< 0.04	0.05535015	4.2127
next station. Queue	0.8039	< 0.03	0.01672849	2.9968
next. Queue	0.6236	< 0.02	0.03029872	2.5567

Replications: 1,000 Time Units: Minutes

Resource

Usage

Instantaneous Utilization	Average	Half	Minimum Average	Maximum Average
labor	0.5846	< 0.00	0.4517	0.7514
truck	0.5384	< 0.01	0.3157	0.8485

Number Busy	Average	Half	Minimum Average	Maximum Average
labor	0.5846	< 0.00	0.4517	0.7514
truck	0.5384	< 0.01	0.3157	0.8485

Number Scheduled	Average	Half	Minimum Average	Maximum Average
labor	1.0000	< 0.00	1.0000	1.0000
truck	1.0000	< 0.00	1.0000	1.0000

Scheduled Utilization	Average	Half	Minimum Average	Maximum Average
labor	0.5846	0.00	0.4517	0.7514
truck	0.5384	0.01	0.3157	0.8485

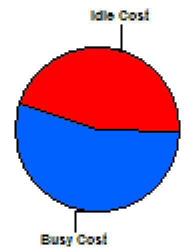
Annex 4: inventory management model

Replications: 1,000 Time Units: Minutes

Key Performance Indicators

	Average
Value Added Cost	258,526
Wait Cost	88,241
Total Cost	346,767

All Resources	Average
Busy Cost	196,407
Idle Cost	162,048
Total Cost	358,454



System	Average
Total Cost	508,814
Number Out	175

Replications: 1,000 Minutes

Entity

Time

VA Time	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entitv 1	209.54	< 0.71	169.53	247.06	0.00226383	1475.40

NVA Time	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entitv 1	0.00	< 0.00	0.00	0.00	0.00	0.00

Wait Time	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entitv 1	291.51	< 7.14	109.87	896.73	0.00	4595.28

Transfer Time	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entitv 1	0.00	< 0.00	0.00	0.00	0.00	0.00

Other Time	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entitv 1	0.00	< 0.00	0.00	0.00	0.00	0.00

Total Time	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entitv 1	501.05	< 7.49	288.77	1121.25	0.02438599	5015.80

Cost

VA Cost	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entitv 1	1551.72	< 6.94	1189.29	1894.92	100.01	23223.12

NVA Cost	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entitv 1	0.00	< 0.00	0.00	0.00	0.00	0.00

Wait Cost	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entitv 1	485.85	< 11.90	183.11	1494.55	0.00	7658.80

Other Cost	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Entitv 1	0.00	< 0.00	0.00	0.00	0.00	0.00

Replications: 1,000 Time Units: Minutes

Entity

Cost

Transfer Cost	Average	Half	Minimum Average	Maximum Average
Entity 1	0.00	< 0.00	0.00	0.00

Total Cost	Average	Half	Minimum Average	Maximum Average
Entity 1	2037.57	< 15.66	1435.96	3064.47

Other

Number In	Average	Half	Minimum Average	Maximum Average
Entity 1	182.30	0.84	142.00	223.00
Entity 2	0.00	0.00	0.00	0.00
Entity 3	0.00	0.00	0.00	0.00

Number Out	Average	Half	Minimum Average	Maximum Average
Entity 1	174.67	0.81	140.00	219.00
Entity 2	0.00	0.00	0.00	0.00
Entity 3	0.00	0.00	0.00	0.00

WIP	Average	Half	Minimum Average	Maximum Average
Entity 1	7.3293	< 0.13	3.5067	17.1813
Entity 2	0.00	< 0.00	0.00	0.00
Entity 3	0.00	< 0.00	0.00	0.00

Replications: 1,000 Time Units: Minutes

Process

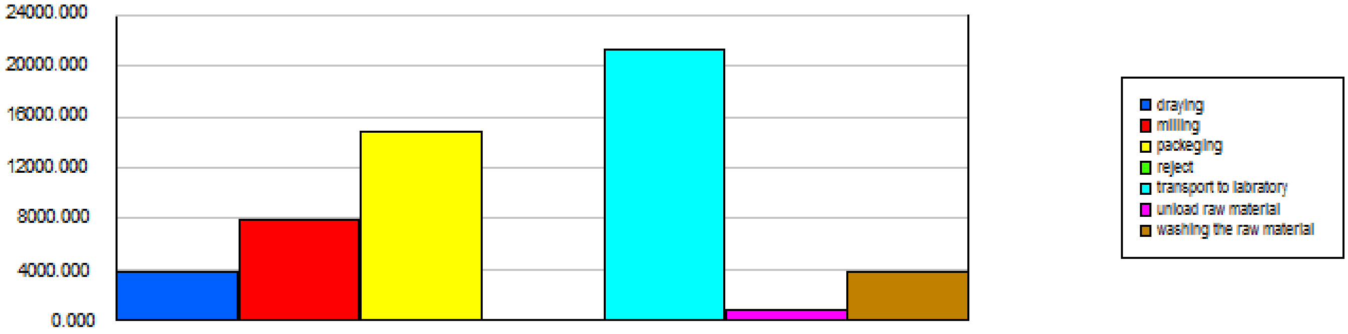
Time per Entity

VA Time Per Entity	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
draying	59.6192	< 0.39	41.2625	83.1612	0.00080139	666.55
milling	69.4510	< 0.43	49.6337	96.1029	0.00025787	745.75
packaging	84.6574	< 0.52	60.8128	118.42	0.00350301	1205.67
reject	1.9706	< 0.16	0.00	16.7205	0.00	20.0852
transport to laboratory	89.0772	< 0.53	62.3701	119.11	0.00077646	1211.29
unload raw material	32.0096	< 0.21	22.2798	44.2474	0.00025527	380.91
washing the raw material	59.6251	< 0.40	40.2911	87.0239	0.00088759	694.84

Wait Time Per Entity	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
draying	42.2373	< 1.39	4.8890	197.17	0.00	917.25
milling	79.1976	< 2.65	16.0306	293.34	0.00	1369.32
packaging	150.74	< 6.33	18.9488	991.47	0.00	2220.22
reject	6.2092	< 1.15	0.00	196.39	0.00	269.18
transport to laboratory	204.66	< 8.76	34.1648	1222.68	0.00	2845.61
unload raw material	9.2594	< 0.26	1.4310	29.3789	0.00	386.48
washing the raw material	42.5108	< 1.36	7.6083	202.20	0.00	995.02

Total Time Per Entity	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
draying	101.86	< 1.65	54.4268	275.14	0.00206654	989.17
milling	148.65	< 2.91	71.0091	370.80	0.00025787	1479.75
packaging	235.40	< 6.62	90.1924	1107.80	0.00658279	2315.94
reject	8.1797	< 1.19	0.00	201.81	0.00	270.21
transport to laboratory	293.74	< 9.05	99.97	1332.89	0.00238644	2975.11
unload raw material	41.2690	< 0.41	25.3667	66.2817	0.00044167	419.59
washing the raw material	102.14	< 1.62	49.0058	271.78	0.00358554	1024.30

Accumulated Time

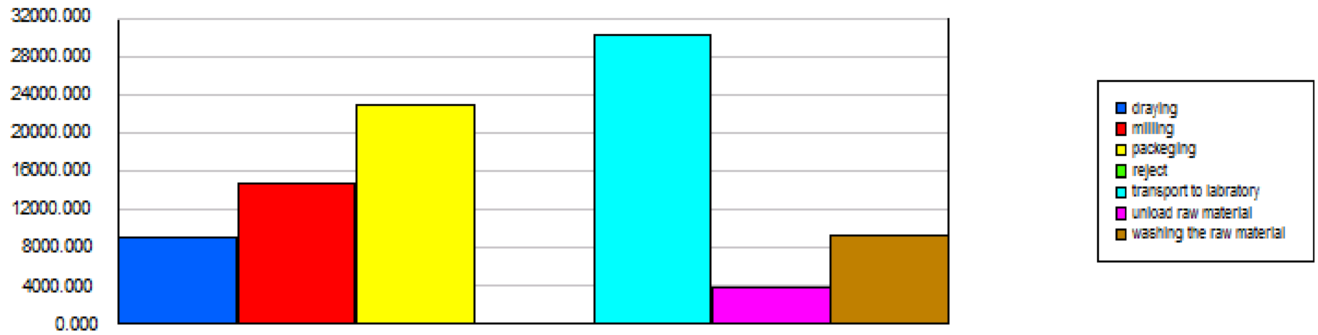


Replications: 1,000 Time Units: Minutes

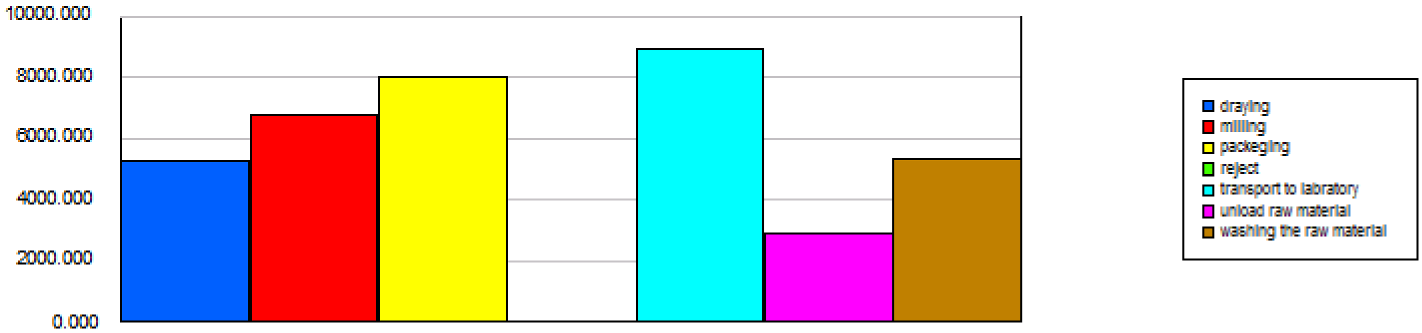
Process

Accumulated Time

Accum VA Time	Average	Half	Minimum Average	Maximum Average
draving	5292.01	48.71	3217.03	8108.25
milling	6746.62	63.55	3879.09	10204.27
packaging	8044.12	74.07	4957.64	11786.12
reject	3.0353	0.26	0.00	31.0027
transport to laboratory	8955.90	77.63	5197.04	12453.80
unload raw material	2892.95	27.27	1656.25	4283.61
washing the raw material	5337.01	51.41	2941.25	8570.60



Accum Wait Time	Average	Half	Minimum Average	Maximum Average
draving	3820.89	137.35	308.01	20505.80
milling	7896.17	296.16	1154.20	34027.05
packaging	14813.12	689.59	1383.26	95181.22
reject	9.3898	1.63	0.00	269.18
transport to laboratory	21301.68	1,018.92	3047.33	127158.20
unload raw material	851.24	26.91	101.60	2879.13
washing the raw material	3882.55	138.90	550.39	22444.48

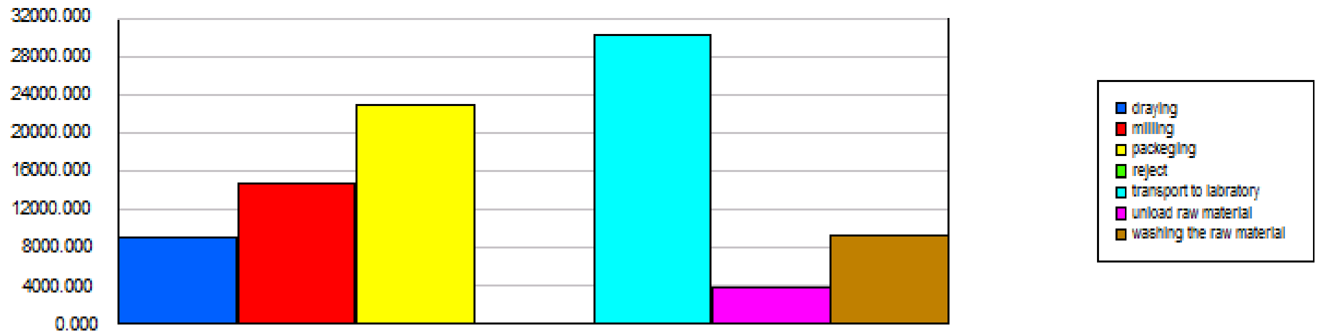


Replications: 1,000 Time Units: Minutes

Process

Accumulated Time

Total Accum Time	Average	Half	Minimum Average	Maximum Average
draving	9112.90	175.96	3550.87	28614.05
milling	14642.79	346.62	5273.51	44055.57
packaging	22857.24	746.48	6584.04	106348.76
reiect	12.4252	1.71	0.00	270.21
transport to laboratorv	30257.58	1,079.19	9197.65	138620.85
unload raw material	3744.20	49.59	1799.88	6877.74
washing the raw material	9219.56	180.14	3577.42	30167.29



Cost per Entity

VA Cost Per Entitv	Average	Half	Minimum Average	Maximum Average
draving	173.89	< 1.13	120.35	242.55
milling	1504.77	< 9.39	1075.40	2082.23
packaging	197.53	< 1.22	141.90	276.31
reiect	5.7146	< 0.46	0.00	48.4894
transport to laboratorv	534.46	< 3.21	374.22	714.65
unload raw material	92.8277	< 0.61	64.6114	128.32
washing the raw material	178.88	< 1.21	120.87	261.07

Replications: 1,000 Time Units: Minutes

Process

Cost per Entity

Wait Cost Per Entity	Average	Minimum Average	Maximum Average
draving	70.3956	8.1484	328.62
milling	132.00	26.7176	488.89
packaging	251.24	31.5814	1652.45
reject	10.3486	0.00	327.32
transport to laboratory	341.10	56.9413	2037.79
unload raw material	15.4323	2.3850	48.9648
washing the raw material	70.8514	12.6805	337.00

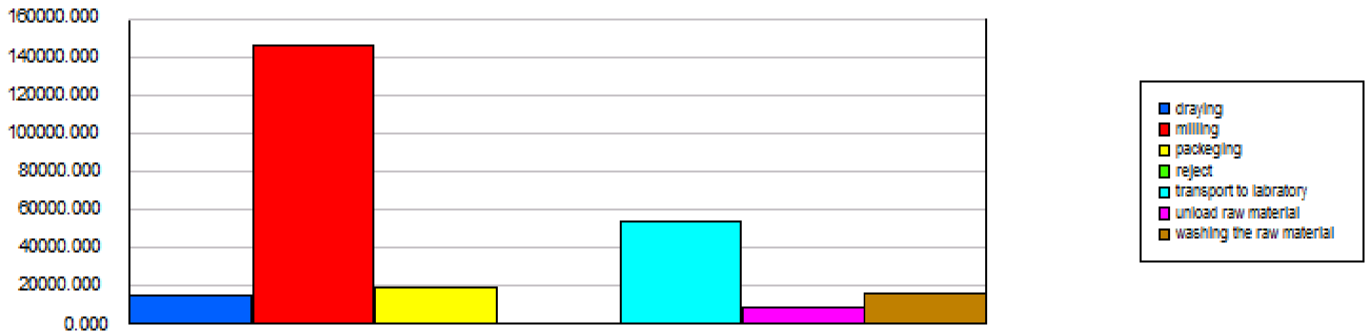
Total Cost Per Entity	Average	Minimum Average	Maximum Average
draving	244.28	142.61	556.01
milling	1636.77	1113.56	2411.76
packaging	448.77	197.82	1923.89
reject	16.0633	0.00	343.04
transport to laboratory	875.57	438.44	2699.10
unload raw material	108.26	70.4379	162.19
washing the raw material	249.73	135.40	545.73

Replications: 1,000 Time Units: Minutes

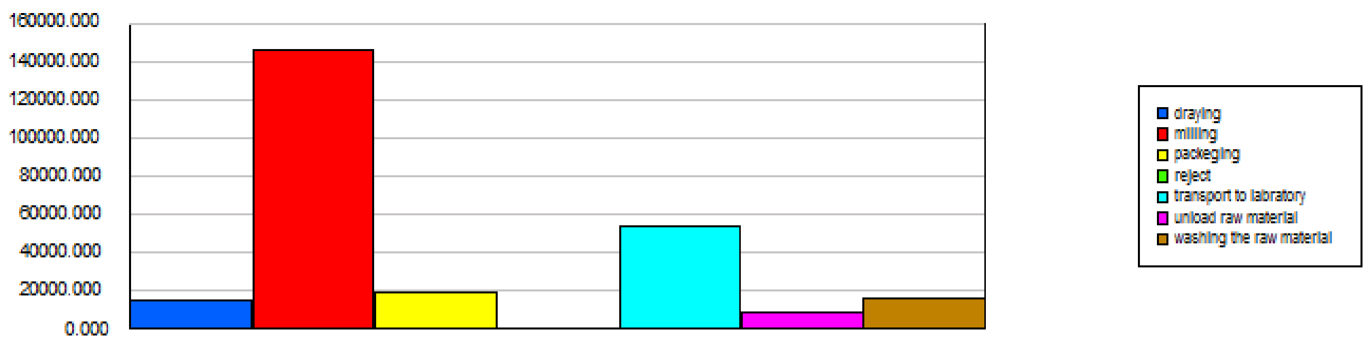
Process

Accumulated Cost

Accum VA Cost	Average	Half	Minimum Average	Maximum Average
draying	15435.02	142.07	9383.01	23649.06
milling	146176.82	1,376.95	84046.91	221092.43
packaging	18769.62	172.83	11567.84	27500.96
reject	8.8025	0.76	0.00	89.9080
transport to laboratory	53735.37	465.81	31182.26	74722.79
unload raw material	8389.57	79.08	4803.11	12422.46
washing the raw material	16011.04	154.23	8823.74	25711.80



Accum Wait Cost	Average	Half	Minimum Average	Maximum Average
draying	6368.16	228.92	513.35	34176.33
milling	13160.28	493.60	1923.67	56711.75
packaging	24688.53	1,149.31	2305.44	158635.36
reject	15.6497	2.72	0.00	448.63
transport to laboratory	35502.81	1,698.20	5078.88	211930.34
unload raw material	1418.74	44.85	169.33	4798.55
washing the raw material	6470.91	231.50	917.32	



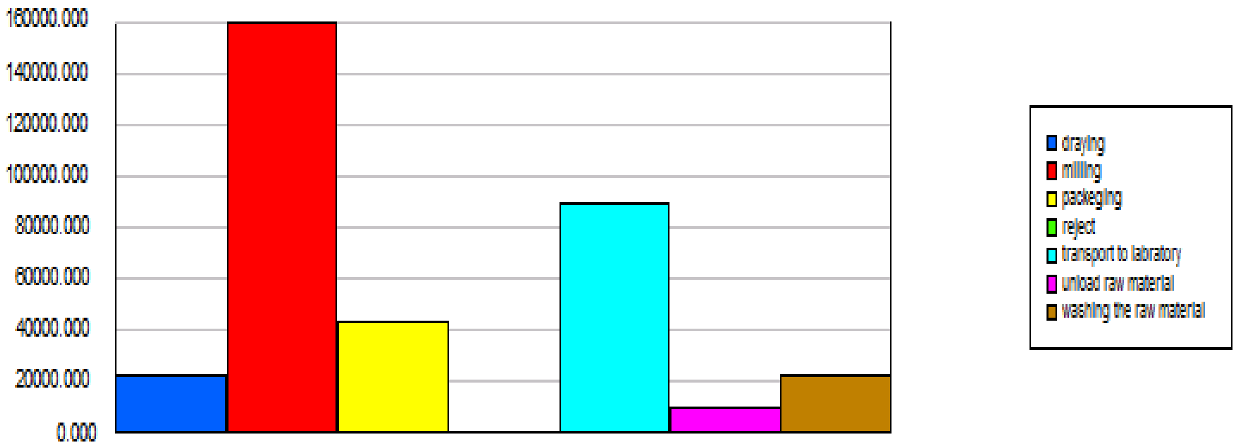
Replications: 1,000 Time Units: Minutes

Process

Accumulated Cost

Total Accum Cost	Average	Half	Minimum Average	Maximum Average
draving	21803.18	346.21	9971.70	57825.39
milling	159337.10	1,779.04	87203.15	277511.27
packaging	43458.16	1,283.42	14440.59	184692.97
reject	24.4522	2.97	0.00	451.63
transport to laboratory	89238.18	2,074.89	38624.76	280706.22
unload raw material	9808.31	114.28	5042.50	16641.07
washing the raw material	22481.96	360.48	9884.04	60575.90

Other

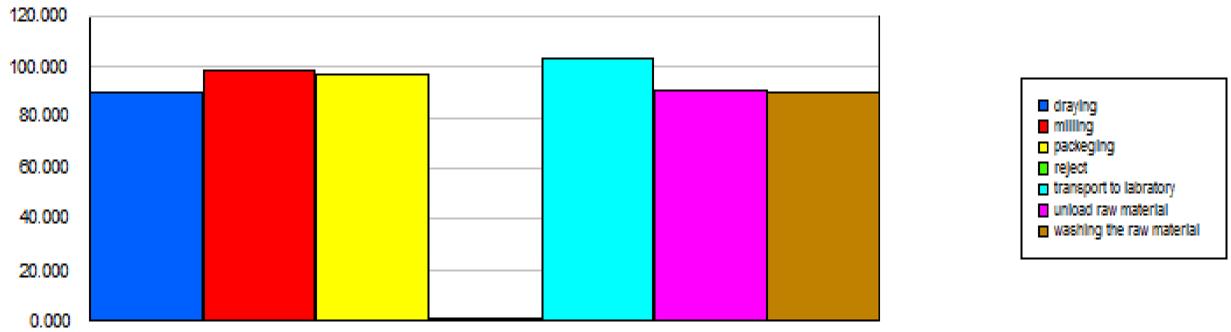


Replications: 1,000 Time Units: Minutes

Process

Other

Number In	Average	Half	Minimum Average	Maximum Average
draving	89.4860	0.60	63.0000	125.00
milling	98.4510	0.69	66.0000	138.00
packaging	97.1310	0.68	66.0000	136.00
reject	0.9870	0.06	0.00	5.0000
transport to laboratory	103.03	0.69	68.0000	139.00
unload raw material	90.7180	0.62	56.0000	126.00
washing the raw material	90.2540	0.60	63.0000	127.00



Number Out	Average	Half	Minimum Average	Maximum Average
draving	88.7850	0.60	61.0000	122.00
milling	97.1310	0.68	66.0000	136.00
packaging	95.0370	0.67	65.0000	134.00
reject	0.9870	0.06	0.00	5.0000
transport to laboratory	100.60	0.67	66.0000	136.00
unload raw material	90.4030	0.62	56.0000	125.00
washing the raw material	89.4860	0.60	63.0000	125.00

Replications: 1,000 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
draying. Queue	42.2323	< 1.39	4.8890	195.66	0.00	917.25
milling. Queue	79.2677	< 2.64	16.0306	293.52	0.00	1369.32
packaging. Queue	150.92	< 6.31	18.9488	981.44	0.00	2220.22
reject. Queue	6.2092	< 1.15	0.00	196.39	0.00	269.18
transport to laboratory.	204.73	< 8.74	34.1648	1222.93	0.00	2845.61
unload raw material. Queue	9.2621	< 0.26	1.4310	29.3789	0.00	386.48
washing the raw material.	42.5736	< 1.35	7.6083	202.20	0.00	995.02

Cost

Waiting Cost	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
draying. Queue	70.3872	< 2.31	8.1484	326.11	0.00	1528.76
milling. Queue	132.11	< 4.41	26.7176	489.20	0.00	2282.20
packaging. Queue	251.54	< 10.52	31.5814	1635.73	0.00	3700.37
reject. Queue	10.3486	< 1.92	0.00	327.32	0.00	448.63
transport to laboratory.	341.21	< 14.57	56.9413	2038.22	0.00	4742.68
unload raw material. Queue	15.4369	< 0.44	2.3850	48.9648	0.00	644.14
washing the raw material.	70.9559	< 2.26	12.6805	337.00	0.00	1658.37

Other

Number Waiting	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
draying. Queue	0.3098	< 0.01	0.02468014	1.6578	0.00	12.0000
milling. Queue	0.6452	< 0.02	0.0925	2.7838	0.00	16.0000
packaging. Queue	1.2252	< 0.06	0.1108	7.6282	0.00	21.0000
reject. Queue	0.00075239	< 0.00	0.00	0.02156873	0.00	1.0000
transport to laboratory.	1.7594	< 0.08	0.2519	10.8943	0.00	20.0000
unload raw material. Queue	0.06863106	< 0.00	0.00814103	0.2307	0.00	6.0000
unload the raw material.	0.00	< 0.00	0.00	0.00	0.00	0.00
washing the raw material.	0.3166	< 0.01	0.04410203	1.7984	0.00	11.0000

Replications: 1,000 Time Units: Minutes

Resource

Usage

Instantaneous Utilization	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
car	0.2327	< 0.00	0.1327	0.3450	0.00	1.0000
drying machine	0.4260	< 0.00	0.2582	0.6563	0.00	1.0000
human	0.7224	< 0.01	0.4180	1.0000	0.00	1.0000
milling machine	0.5438	< 0.01	0.3108	0.8186	0.00	1.0000
packaging machine	0.6493	< 0.01	0.3972	0.9460	0.00	1.0000
washing machine	0.4297	< 0.00	0.2357	0.6867	0.00	1.0000

Number Busy	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
car	0.2327	< 0.00	0.1327	0.3450	0.00	1.0000
drying machine	0.4260	< 0.00	0.2582	0.6563	0.00	1.0000
human	0.7224	< 0.01	0.4180	1.0000	0.00	1.0000
milling machine	0.5438	< 0.01	0.3108	0.8186	0.00	1.0000
packaging machine	0.6493	< 0.01	0.3972	0.9460	0.00	1.0000
washing machine	0.4297	< 0.00	0.2357	0.6867	0.00	1.0000

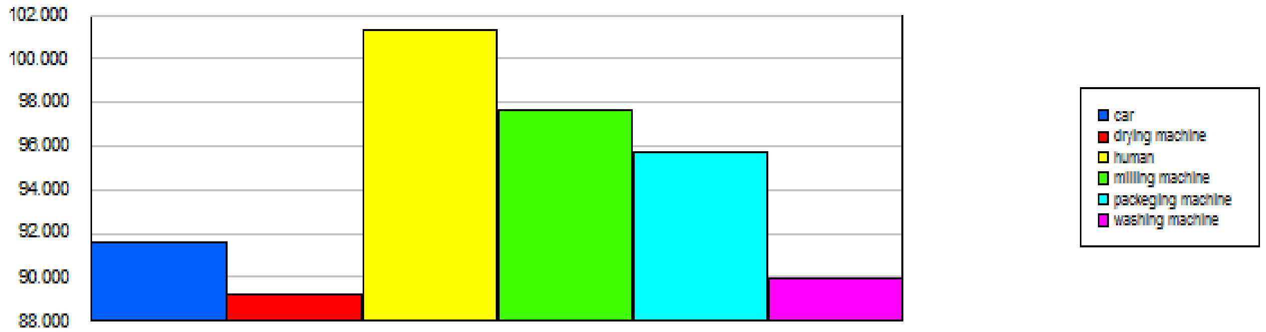
Number Scheduled	Average	Half	Minimum Average	Maximum Average	Minimum Value	Maximum Value
car	1.0000	< 0.00	1.0000	1.0000	1.0000	1.0000
drying machine	1.0000	< 0.00	1.0000	1.0000	1.0000	1.0000
human	1.0000	< 0.00	1.0000	1.0000	1.0000	1.0000
milling machine	1.0000	< 0.00	1.0000	1.0000	1.0000	1.0000
packaging machine	1.0000	< 0.00	1.0000	1.0000	1.0000	1.0000
washing machine	1.0000	< 0.00	1.0000	1.0000	1.0000	1.0000

Replications: 1,000 Time Units: Minutes

Resource

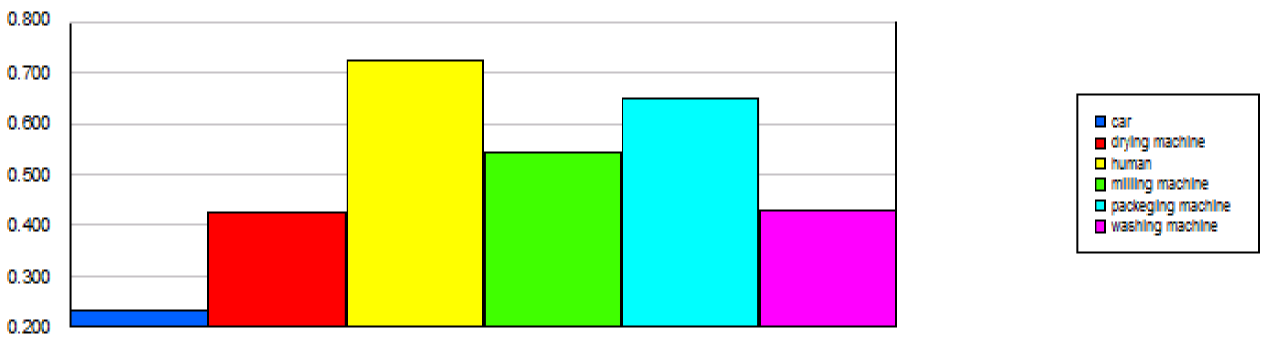
Usage

Scheduled Utilization	Average	Half	Minimum Average	Maximum Average
car	0.2327	0.00	0.1327	0.3450
drying machine	0.4260	0.00	0.2582	0.6563
human	0.7224	0.01	0.4180	1.0000
milling machine	0.5438	0.01	0.3108	0.8186
packaging machine	0.6493	0.01	0.3972	0.9460
washing machine	0.4297	0.00	0.2357	0.6867



Total Number Seized	Average	Half	Minimum Average	Maximum Average
car	91.6350	0.63	56.0000	127.00
drying machine	89.2010	0.60	62.0000	123.00
human	101.30	0.67	67.0000	137.00
milling machine	97.7030	0.68	66.0000	136.00
packaging machine	95.7390	0.67	66.0000	134.00
washing machine	89.9110	0.60	63.0000	126.00

Cost

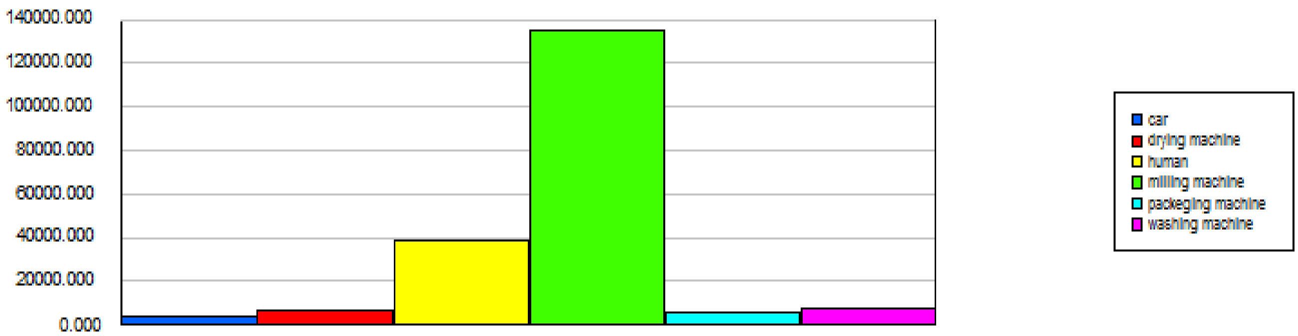


Replications: 1,000 Time Units: Minutes

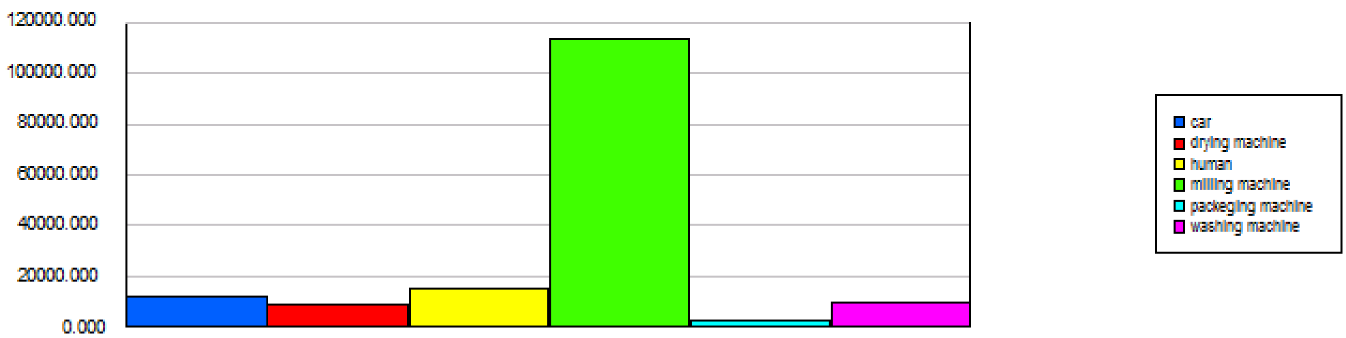
Resource

Cost

Busy Cost	Average	Half	Minimum Average	Maximum Average
car	3571.72	33.64	2042.70	5285.14
drying machine	6615.01	60.89	4021.29	10135.31
human	38808.88	336.42	22520.52	53966.46
milling machine	134932.45	1,271.03	77581.76	204085.32
packaging machine	5362.75	49.38	3305.10	7857.42
washing machine	7116.02	68.54	3921.66	11427.47



Idle Cost	Average	Half	Minimum Average	Maximum Average
car	11810.28	33.68	10081.51	13349.30
drying machine	8954.92	60.99	5361.70	11572.63
human	15012.73	337.81	0.00	31475.97
milling machine	113861.38	1,273.41	45279.04	172018.24
packaging machine	2917.74	49.40	449.38	5014.90
washing machine	9490.50	68.66	5212.53	12718.34



Replications: 1,000 Time Units: Minutes

Resource

Cost

Usage Cost	Average	Half	Minimum Average	Maximum Average
car	0.00	0.00	0.00	0.00
drying machine	0.00	0.00	0.00	0.00
human	0.00	0.00	0.00	0.00
milling machine	0.00	0.00	0.00	0.00
packaging machine	0.00	0.00	0.00	0.00
washing machine	0.00	0.00	0.00	0.00

User Specified

Counter

Count	Average	Half	Minimum Average	Maximum Average
production	32027.47	< 224.30	21905.00	45158.00
record raw material	33263.83	< 220.83	22110.00	44555.00